Markets and the Use of Knowledge

Testing the «Hayek hypothesis» in Experimental Stock Markets

By

Klaus Beckmann and Martin Werding

–April 1994–

Universität

We are indebted to our supervisors at the Universität Passau, Professors Reinar Lüdeke and Gerhard Kleinhenz, for taking charge of the PWB project and giving us ample scope to look into side issues as well. Their comments and suggestions—both general and on a draft of the present paper—have been invaluable.

Dr. Neil Jackson kindly weeded out a host of errors (grammatical, semantic, and worse) that we had been unable to avoid.

While their help is acknowledged gratefully, we would not implicate these kind people for such errors and omissions as remain.

Authors' Addresses:

Klaus Beckmann Martin Werding

Universität Passau, Lehrstühle für Volkswirtschaftslehre mit Schwerpunkten Finanzwissenschaft und Wirtschaftspolitik
(Professoren Dr. Reinar Lüdeke und Dr. Gerhard Kleinhenz)

Innstraße 27, 94032 Passau, Germany

☎ (0851) 509-228 (Beckmann) and 509-165 (Werding)

wfbeck02@fsuni.rz.uni-passau.de (Beckmann)
wfwerd01@fsuni.rz.uni-passau.de (Werding)
wfwahl01@fsuni.rz.uni-passau.de (PWB)

Abstract

A broad strand in experimental economics has been devoted to testing the «Hayek hypothesis», which is commonly understood as the proposition that competitive markets conform to basic efficiency postulates. The precise content of this hypothesis, however, often remains fairly vague.

We begin by restating the «Hayek hypothesis» in the light of theoretical work, which leads us to identifying three central elements of the hypothesis. Building on this restatement, we review the literature on experimental (market) economics and show how this literature has progressed from testing the first element of the «Hayek hypothesis» to testing all three elements simultaneously.

Very recently, a number of scholars have moved these tests out of the laboratory, establishing political stock markets as a new type of field experiment. These political stock markets can be viewed as the toughest tests the «Hayek hypothesis» has been subjected to so far, and they have tended to support it.

In the final section of the present paper, we outline some design features of the «Passauer Wahlbörse» (PWB), an ongoing political stock market experiment being run at the Universität Passau, and indicate a few differences between this experiment and previous work.

JEL classification: C9, (D8)

Keywords: Hayek hypothesis, competition, information, experimental economics, political stock markets

"Der Wettbewerb ist im wesentlichen
ein Prozeß der Meinungsbildung..."
Friedrich A. von Hayek [1946]

"Why, any college Soph would know
Who took Ec One, and pulled a 'D',
That prices, if you let them go,
Will guide our conduct prop–er–lee."
Bruce Knight [1976]

The central problem in economics basically involves *scarcity*, *change*, and *imperfect information*. While invoking scarcity verges on the commonplace (at least it should for an economist), the economics of imperfect and asymmetric information are a comparatively recent branch of our field, and it is only in the last few decades that mainstream economics has rediscovered change. All in all, the economic problem is one of co-ordinating individual activities in an environment where society's resources are limited, and where both their availability and the opportunities to employ them are subject to continuous change; moreover, the particular knowledge of all the relevant circumstances which is required to make the best use of available means is not simply "given" in its entirety, but is affected by uncertainty and, above all, dispersed among large numbers of individuals.

There is a strong tradition in economic thinking that *competition* on markets, in conjunction with a price system unhampered by any rigidities and manipulations, is particularly well-suited to utilizing the knowledge dispersed throughout society, to economizing resources, and to handling change. This mechanism is supposed to work by leaving scope for decentral decision–making and by providing incentives to make use of private information. As Friedrich A. von

Hayek is one of the chief proponents of this tenet, the above proposition is often labelled the «Hayek hypothesis».[1]

Theoretical reasoning has developed a lot since the rigorous critique applied by Hayek [1945, 1968] to economists' understanding of competition, market dynamics and equilibrium: It has set up models in which informational *decentralization* can be dealt with explicitly (Hurwicz [1972]; Lucas [1972]). Furthermore, theorists have begun to investigate the process of *acquiring* information which is to be aggregated and disseminated by the market (e.g. Grossman and Stiglitz [1980]).

Generally speaking, the whole body of these formal approaches provides some (modest) support for Hayek's claim concerning competition. But nevertheless, theory still cannot do justice to the richness of any field environment, and theorists seem always on the point of committing exactly what Hayek disliked most about them: taking for granted that a "competitive rational expectations equilibrium", for example, already exists or is easy to achieve, whereas they ought rather to demonstrate that it is likely to be the outcome of a competitive process.[2]

Experimental economics endeavours to do just this. It emerged during the 1960s as a new branch of economic research. Obviously, experimental research was (and is) driven by contemporary theoretical progress; yet, it was meant to contribute to a better understanding of market mechanisms at work than theory could provide on its own.[3] In the vast majority of cases,[4] the laboratory

---

[1] Hayek advanced his position in a less formal manner than modern theorists are wont to do. Perhaps the true reason for this is that (as yet) there does not exist a formalized apparatus of economic theory that is germane to Hayek's view. See section 1.

[2] Cf. Hayek [1946, 124f.]

[3] Plott [1979, 138–141] gives an interesting discussion of how economic experiments can interface with theoretical research.

evidence gathered so far confirms economists' faith in competition, and this appears to hold true even in rather complex environments featuring uncertainty, and asymmetric or diverse information.[5]

Questions open to further research arise from the problems of testing information *acquisition* in a competitive environment and, to a certain degree related to this, from the shift to experimental settings that come close to a *field environment*. The most elaborate example for this last step may be seen in the «Iowa Presidential Stock Market» (henceforth IPSM) conducted by Forsythe et al. during the 1988 election campaign in the United States (iid. [1991]).

Forsythe and his colleagues linked market design and incentive structures familiar from laboratory experiments to the question of how the 1988 US presidentials would end up—that is, to a complex question, the answer to which nobody (including the experimenters) knew beforehand. The accuracy of prediction they achieved is impressive. All the same, there appears to be enough room for further inquiry (a) into the process of information gathering led by competitive incentives in general, and (b) into the relevance of the institutional design of experimental markets for the outcome of such competition.

Ironically, this variety of experimental work meets another objection made by Hayek [1968], who asserted that the validity of his hypothesis *could not* be tested empirically—at least, not beyond some artificially created laboratory situations, where the facts which competition was intended to discover were already known to the observer—because the results of competition as a "discovery procedure" were, by nature, unpredictable.[6] Evidently, this statement

---

[4] We confine our attention to experimental analysis of market performance (in its broadest sense) here. While this is arguably the largest strand of experimental research, we are aware of work done in other directions—public choice, for instance—as well.

[5] For a more detailed review of both theoretical and experimental inquiry into the the significance of the «Hayek hypothesis», see section 2.

[6] Cf. Hayek [1968, 255 and 258f.]

has not deterred experimental economists either from carrying out laboratory tests—the practical value of which Hayek tended to view with scepticism—or from developing experiments in a field environment of sorts. The key advantage of a political stock market is that although election results are unknown ex ante, the market's success in predicting them *can* be gauged by comparing stock prices to the election outcome, ex post.

For the present paper, a threefold task arises from these general reflections. First, the precise contents of the «Hayek hypothesis»—which have been given insufficient attention in experimental literature—will be examined more closely (section 1). In section 2, we will review the relevant developments in experimental economics in some detail. And finally, we shall outline some design features of a political stock market which we set up in Passau, Germany, in January 1994 and which we will be continuing to run until October of the same year. This market differs in a number of significant ways from its predecessors, aspects which will be treated in section 3.

1. The «Hayek hypothesis» restated

Quite a lot of empirical work, encompassing both experiments and field studies, has been concerned with testing Hayek's [1945, 1968] claim that markets handle information efficiently.[7] The precise content of this hypothesis, however, often remains unspecified, and where there is a definition—as in Davis and Williams [1991]—, it appears too narrow to do full justice to the Hayek hypothesis.

---

[7] See the following section for a brief survey.

Broadly speaking, the hypothesis contains three main propositions about the functioning of markets or, to be more precise, *competitive exchange*:

- Competitive markets lead to allocations which fully exhaust the available gains from trade.
- Competition co-ordinates individual activities in such a way that individuals decide as if they had access to society's entire stock of information, although each of them possesses but a tiny fragment of it. And because society is spared the expense of explicitly collecting, aggregating, and disseminating this tremendous amount of information—a task which might well prove impossible—, competition as a coordination mechanism is superior to alternative ones.
- Competition provides incentives for individuals to discover (or create) new pieces of information. Moreover, price signals, which encapsulate all of society's present knowledge, guide individual research efforts in the right direction.

The first proposition is, of course, the usual textbook conclusion that a competitive market equilibrium is—provided a number of limiting assumptions hold—Pareto-optimal from a *static* point of view.[8] It is this best known part of the «Hayek hypothesis» that was first subjected to experimental testing, with more or less satisfying—and, for an economist, reassuring—results.[9] Some experimenters (e.g. Smith [1982], Davis and Williams [1991]) have even reduced the Hayek hypothesis to be identical with the first proposition.[10]

---

[8] Kreps [1990, chs. 6–8] or Varian [1993, ch. 13] provide examples of how this conclusion is presented and discussed in a modern microeconomics text.

[9] Again, the reader is referred to section 2 for further references.

[10] Davis and Williams [1991, 264–265]—referring to Smith [1982, 166f]—distinguish two formulations of this proposition, one of which is given above. The other formulation claims that markets lead to competitive equilibrium pricing.

In the last two decades, a huge and controversial body of literature has centred around the second part of our definition: the literature on "rational expectations". While the static efficiency proposition does not pay particular attention to informational aspects,[11] rational expectations theory starts out from an explicit acknowledgement of the impact of market prices on expectations and, hence, individual market demand.[12] In this framework, there is some scope for market prices to transfer information from one individual to the other (see, for instance, Grossman [1981]). Traders' bids on the market (partially) *reveal* such information as these individuals possess, and other traders—if they are rational—will use the consequent price signals to update their own beliefs. These updated beliefs, in turn, will be reflected in their market acitivities, offering further evidence on which others may condition their calculations. In equilibrium, it must be the case that everyone is "content with their decision", so that, given the current market prices, there is no incentive for anybody (a) to revise their belief system or (b) to engage in further exchange. This natural extension of the ordinary equilibrium concept[13] to a world of uncertainty and asymmetric information

---

[11] There is a close connection between the first two propositions. Obviously, competitive market prices in textbook microeconomics do convey information—about marginal costs and marginal valuations. However, it is probably fair to argue that the second proposition goes further than that. Amongst other things, it (a) accomodates revelation and aggregation of additional kinds of information and (b) treats the implicit market(s) for information linked to "ordinary" markets for goods and services explicitly. See section 2 for further remarks in the context of experimental economics

[12] It is perhaps a bit misleading to say that "market prices are not merely determined by endowments and preferences of traders but also, in part, determine these preferences" (Sunder [1992, 667]). One would tend rather to think of individual preferences for commodities as given, while market demand changes as individuals receive different information about the likelihood of future states of the world (and, hence, the restrictions for their optimizing problem).

[13] This idea underlies the idea of static Walrasian equilibrium, as well as the common "solution concepts" in game theory. See Kreps [1990] for a discussion. Note that the first condition may be interpreted as the equilibrium condition for the implicit market for information, while the second describes goods market equilibrium.

requires that if information acquisition is costless, market prices must *fully reflect* all of society's relevant knowledge. Besides information revelation, (competitive) market prices thus achieve *information aggregation* as well.

Hayek's conception of competition as a "discovery procedure", however, is broader and inherently more dynamic than the rational expectations hypothesis:

> "This means that the, in some respects always unique, combinations of individual knowledge and skills, which the market enables them to use, will not merely, or even in the first instance, be such *knowledge of facts as they could list and communicate* if some authority asked them to do so. The knowledge of which I speak consists rather of the *capacity to find out particular circumstances*, which becomes effective only if possessors of such knowlege are informed by the market which kinds of things or services are wanted, and how urgently they are wanted." (Hayek [1968, 257]. Italics added.).

Beyond the mere communication of such pieces of information that the individual happens to possess without any research efforts and the inference of similar exogenous pieces of information from the market activities of other parties, Hayek clearly envisaged the discovery of *new* information as a central function to be fulfilled by individuals in a competitive system. Current market prices, reflecting society's knowledge in statu quo, direct individual research efforts into (socially) profitable fields—in the same manner in which they guide other resources into their most valued use. This third and final aspect of the Hayek hypothesis clearly goes beyond the claim to static allocative efficiency and even transcends the ("semi-dynamic") contention that competitive pricing fully reveals such information as is supplied exogenously and gratuitously, be it ever so dispersed.

But is this hypothesis internally consistent? To this question, most scholars would reply that it is not: its *static part* (the first statement and, presumably, the lion's share of the second) is taken to be at

odds with the *dynamic* one. A related and well-known point was first raised in the literature on "workable" competition,[14] which pointed out that neoclassical individuals or firms lack any incentive to innovate, since competitive advantages would erode instantly in a (static) neoclassical world, leaving nothing to remunerate the innovator for his trouble. In a seminal paper, Grossman and Stiglitz [1980] brought this idea to bear on the rational expectations hypothesis.[15] The gist of their argument goes as follows:[16] A (rational expectations) equilibrium is characterized by the *compatibility* of individual beliefs and plans. This means that no-one can have an incentive to revise his decisions, including the decision to get informed. An obvious condition for this is that the net expected utility (or the net expected return, which is the same in this model) for both types of traders be equal. In the presence of information costs, this requires the (expected) gross return of the informed to exceed that of the uninformed. This, however, can only occur if the equilibrium price of the risky asset does not fully reflect all of society's information. Hence, there is a conflict between the naïve

---

[14] See, for instance, Clarke [1940], Kantzenbach [1967], or the recent overview article by Mückl [1988]. Schumpeter [1987] argues in a similar vein. The German literature coined the nice term "Schlafmützenkonkurrenz" to capture the essence of this conflict between the neoclassical and dynamic views of competition.

[15] Wihlborg [1991], in comparing market activities to the efforts of motor-car drivers to circumvent traffic jams by lane switching, gives a particularly illustrative and interesting example.

[16] As an analytical framework, the two authors use the model of a simple financial market with two assets, a riskless and a risky one. The return to the risky asset depends on two stochastic variables, one of which is observable at a certain cost while the other cannot be observed. All agents are assumed to have rational expectations of the ordinary variety. In this framework, bids by traders who have acquired information as to the true outcome of the observable draw reveal information to the uninformed agents. Because the latter cannot distinguish between price changes due to the formers' superior knowledge and changes due to "noise", this revelation is only partial. Excepting the cost of information acquisition and the concomitant presence of two types of individuals (the size of each group being endogenous), Grossman and Stiglitz' [1980] model is akin to the setup in Lucas [1972].

formulation of the fully revealing rational expectations part of the Hayek hypothesis and the claim that markets function as a "discovery procedure". From the point of view of static allocative efficiency, there is a related problem because information, once it has been obtained, is non-rival in consumption, so that we would want it to be made available to everybody—which is not feasible if we desire information to be acquired at all. This *public goods problem* brings us up against the "Schumpeterian trade-off".[17]

So far we have presumed that there is some "noise" precluding the uninformed from learning the entire knowledge the informed possess. In fact, this noise provides a *mechanism* for the informed *to exclude the uninformed*. In the absence of such a mechanism, information becomes a pure public good, and traders have incentives to free-ride on each other's information-gathering activities. Note, however, that traders do *not* find themselves locked in a prisoners' dilemma situation where "defection" (free-riding) is a dominant strategy. As Grossman and Stiglitz [1980, 395 and 404–405] point out, becoming informed is in fact the best response if all others choose to stay uninformed, and, consequently, "cooperation" is not strictly dominated. Restricting our attention to the two-agent case,[18] we can see easily that the game boils down to a generic "Battle of the Sexes", which is well known to have multiple (Nash) equilibria in both pure and mixed strategies.[19] It does not come as a surprise, therefore, that Grossman and Stiglitz [1980, 395] cannot identify a single competitive equilibrium if information is non-excludable:

> "In the limit, when there is no noise, prices convey all information, and there is no incentive to purchase information. Hence, the only possible

---

[17] See Nelson and Winter [1982] for an in-depth discussion.

[18] And assuming, as Grossman and Stiglitz [1980] do, identical individuals.

[19] cf., for instance, Kreps [1990, ch. 12], Fudenberg and Tirole [1991, 18–22]. Copeland and Friedman [1992] give a game-theoretic interpretation of some experimental results which is akin to the present argument.

> equilibrium is one with no information. But if everyone is uninformed, it clearly pays some individual to become informed. Thus, there does not exist a competitive equilibrium."

In the other limiting case, information acquisition does not carry a cost. This case—which is relevant, for instance, for such information as can be gathered as a (costless) by-product of one's other activities—has been thoroughly dealt with by Grossman [1981], who showed that the fully revealing rational expectations hypothesis holds under these conditions, regardless of whether the benefits from information gathering are excludable or not.

Analyses such as those performed by Grossman and Stiglitz [1980], however, may well fail to bring out the main source of conflict between the first two parts and the third part of Hayek's hypothesis. The former rest on the usual neoclassical concept of equilibrium,[20] which prevails if opposing forces are balanced and individual optimizing is mutually compatible, so that there is no incentive for any agent to change anything. Although there have been attempts to incorporate change into neoclassical models,[21] this change has necessarily been *reactive*;[22] things change because individuals *adapt* to shifts in the constraints they face. To put it bluntly, nothing significantly new can emerge in a model based on equilibrium concepts, unless its designer put it there in the first place.

Clearly, this is not germane to the rôle of competition as a "discovery procedure". If we are to model this process, we have to take *creativity* into account, and this will probably mean jettisoning the idea of equilibrium—except, perhaps, as an attractor in a model of

---

[20] Which, in fact, we have invoked twice when presenting them.

[21] See Semmler [1994] for a very recent reference.

[22] See Witt [1992a].

chaotic dynamics.[23] As Hayek was wont to point out, it is a sign of ill-advised hubris on the modeller's part to proceed as if he knew everything—hubris because this is patently untrue, and ill-advised because this procedure insinuates that the results of competitive market processes can be computed ex ante.[24]

So how are we to reconcile the conflicting portions of the «Hayek hypothesis»? In this paper, we intend to suggest two possible approaches to bringing about such a reconciliation. As to the first approach, we start by noting that there may not be much of a conflict after all if the different propositions of the hypothesis refer to different "worlds" with distinct phenomenological attributes. We may conceive of each of the propositions as a *conditional* statement about the (positive and normative) properties of competitive exchange, advanced on the premise that the underlying model captures reality to a sufficient degree. Furthermore, we add the obvious observation that there may be times and places in an economy which are depicted well by static models, "steady state" settings with recurring transactions of a similar nature and no fundamental discoveries to be made, whereas other sectors (and periods of time) in the same world thrive on creativity, change, and vitality.[25]

If, however, we apply the propositions of the «Hayek hypothesis» separately and selectively to the various sectors (or phenomena, or periods of time) we risk severing the links between these parts. The «Hayek hypothesis» might become a mere list of theorems bearing a

---

[23] The recent collection edited by Day and Chen [1993] contains several papers that are relevant here, some of them expressly dealing with price formation on securities markets.

[24] This claim, undisputed in much of conventional economic theorizing, carries important policy consequences, since it provides the underpinnings for theory-directed interventions.

[25] Of course, some of this commotion will always carry over to the safe havens. We do not purport to present a rigorous analysis here.

superficial likeness (in that they are optimistic about the normative evaluation of competitive markets).

If one feels unhappy about this state of affairs—as we do—, one might seek a solution that integrates the various parts of the «Hayek hypothesis» into a coherent whole. This suggests that it should be supplemented by the following fourth claim:

- When faced with situations that differ in the degree of dynamism, competitive exchange "strikes the right balance" between its static and dynamic functions and predictions, both positively and normatively.

To be sure, this is a *very* bold statement. Taken at face value, it implies (among other things) that competition brings about an optimal level of research and development effort, technological innovation, and scientific invention—a area generally held to be rife with "market failures". No state intervention would be needed to reach the social optimum vis-à-vis the Schumpeterian trade-off, so that we might dispense with patent laws and government-subsidized research altogether.

The chances are that there are not many economists in the world who would second this view wholeheartedly. On the other hand, theoretical argument against this "Hayekian proposition" does not, to date, appear very convincing either. For one thing, this is because we face some difficulties in specifying an adequate point of reference that might serve as a baseline for normative evaluation in this field. For another, we still seem to lack a satisfactory theory of dynamic change in a competitive environment. And, finally, it will not be sufficient to reject the above strong formulation of the «Hayek hypothesis»; additionally, one needs to pinpoint alternative mechanisms that surpass competitive exchange in allocating resources, handling information, and accomodating change.

In the present paper, however, we are not concerned with what theoretical economics may contribute to these questions (neither do we want to delve any further into its past contributions that are of

interest here). Rather, we deal with the rôle of experimental economics in gathering evidence relevant to assessing the validity of the «Hayek hypothesis»—taking its elements both seperately and jointly.

2. Review of the experimental literature

Even though the «Passau political stock market» which we intend to describe in section 3 is more of a field experiment,[26] it is worth reviewing the evolution of laboratory tests from their very beginning. A good part of the basic design of political stock markets stems from such work, as does the knowledge required for running such markets. Moreover, it is quite instructive to see how experimental questions and hypotheses on which political stock markets focus arise as a consequence of previous work. A broad strand of the literature on economic experiments[27] can be interpreted as representing gradual progress in succesively testing the three aspects of the «Hayek hypothesis» distinguished before.

About ten years ago, Smith [1982], reviewing experimental evidence on the Hayek hypothesis, counted a total of 150 to 200 individual tests which constituted the whole body of writing at that time.[28] Since then, experimental economics has been given increased

---

[26] For reason which we will discuss later in this section we join Forsythe et al. [1991] in their classification.

[27] Other fields to which experimental economics has extended after some "formative years" are: trading institutions and other features of institutional design; provision of public goods and the related question of mechanisms for preference revelation; income distribution and concepts of distributive justice; and, more recently, experiments which are designed to test certain hypotheses of game theory. For a survey, cf. Smith [1991].

[28] Cf. Smith [1982, 170].

impetus from additional interest in «rational expectations theory», and the number of studies has multiplied. Therefore, we will content ourselves with a selective survey of a few key developments which have led to the present state of experimental work.[29]

Smith's 1982 article, in a sense, rounds off the experimental efforts of the previous two decades, which Smith himself called the "formative years": Up to that point, experimenters had mostly concentrated on the problem of aggregating strictly *private information on individual preferences*, as induced by monetary incentives to purchase or sell units of an arbitrary good.[30] For reasons of terminological convenience, as well as in order to promote orderly thinking on the point we are pressing here, we would like to refer to such work as testing a market's capacity to *attain competitive equilibrium*, or to exhibit information revelation, under laboratory conditions, rather than speaking of information aggregation or dissemination in the sense which was elucidated in section 1. Hence, we suggest that this early stage of experimental economics should, in our terms, be interpreted as devoted to testing the first proposition which is encapsulated in Hayek's hypothesis.[31]

In the first experiments, participants were divided into two groups, assigned as "buyers" or "sellers", prior to trading. The environment was completely stationary, i. e. supply and demand schedules were held fixed for quite a number of replications during which prices generally converged, at astonishing speed, towards competitive equilibrium levels. This, of course, conformed to the predictions of

---

[29] Readers who are interested in further details of the experiments which we select here may refer to the appendix. There, we try to give a full survey of the evolution of laboratory tests on the «Hayek hypothesis».

[30] Cf. Smith [1976a] for the theoretical underpinnings.

[31] See section 1. In the appendix, we use the abbreviation "HH 1" as a short hand in order to characterize experiments of this type.

standard neoclassical microeconomics. Efficiency was measured by a coefficient of price convergence, or by the after trade allocation of units of the traded good and was, throughout, fairly high. Treatment variables were different slopes of aggregate supply and demand schedules and, hence, different proportions between sellers' and buyers' rents (Smith [1962, 1965]); or the use of trading institutions, such as oral double auctions, (one sided) ask or bid auctions, posted offer markets, and sealed bid auctions (Smith [1964, 1976b]).

Since the task of attaining competitive equilibrium was apparently met by experimental markets in these simple settings, experimenters extended their interest to the additional problems arising from unforeseen, but cyclical, *shifts in demand*. Periods of trade were subdivided into "seasons" but identically repeated as before. Either "buyers" or a new group of "traders", who were the only ones allowed to buy units of the respective good in season 1 for resale in the following season, were meant to learn about future supply and demand. By successful *speculation*, they contributed to establishing an intertemporal equilibrium price level, as distinct from each season's autarchic equilibrium prices (Miller et al. [1977], Williams [1979]).

With the exception of some tests using posted offer or sealed bid institutions, all the experiments up to this date were carried out by *oral auctioning*. Hence, there were additional sources of information available to participants other than price quotations, such as occasional moans or sighs, or multiple acceptance. Although these occurrences, strictly speaking, are against the rules governing experimental markets, they are mostly unavoidable with oral trading institutions.[32] In order to eradicate these disturbances, and to simplify the task of recording data, experimental economists started

---

[32] Cf. Williams [1980, 256], Plott and Sunder [1982, 687f].

in the late 1970s to work with *computerized markets* (Williams [1980]). Apart from the need for appropriate software and the experimenters' interest in whether computerized trade would work as well as most of the oral experiments had done, market design and experimental intentions remained roughly the same as before.

At first, however, the results with automated trade were not very encouraging. Price convergence was much more erratic than before and was not entirely satisfying within a limited number of replications. It appeared that, with computerized trade, the experience possessed by the participants started to matter, at least in terms of some familiarity with the display of information and the use of the mechanical tools which were available to traders (Williams [1980], Smith [1982]). Besides, the question as to exactly how to model a double auction in a computerized environment turned out to be crucial. In any case, automated trade required precise rules governing the sequence in which price quotations were displayed to the market. The whole market process was substantially slowed down as long as all single bids and asks were admitted one after another, each being announced to other participants for some minimum time. Things were no different if, instead, subsequent quotations were queued according to their time of entry, when previous offers were still outstanding. Traders, even if they were willing to proceed towards competitive equilibrium prices, appeared to be "locked in" with such inflexible institutions. However, it proved possible to overcome these problems by establishing an "improvement rule" which forced subsequent price quotations to continuously reduce the bid–ask spread (Williams [1980]) and, finally, by replacing the above-mentioned "time queue" with a so-called "rank queue", in which any offer was placed according to its

rank in the price scale (Smith and Williams [1983]).[33] Given these alterations, and given the presence of experienced traders, computerized double action markets generally confirmed all the standard results concerning price behaviour and market efficiency in commodity trade when buyers and sellers hold strictly private information on individual preferences.

It is not easy to draw a line between, for example, Miller's et al. [1977] and Smith's [1982] experimental designs—as far as cyclical demand or irregular shifts in demand are involved—and some of the later experiments in markets for multi–period lived assets where no further source of uncertainty is present.[34] With respect to their theoretical background, however, the latter tests should be regarded as special cases of an essentially new type of experiment. To our thinking, most of the experimental work subsequent to Smith [1982] is designed primarily to explore a market's capacity to *aggregate relevant information* which is dispersed across individuals. Individuals therefore face additional, and sometimes differing, degrees of *uncertainty* about the likelihood of various states of the world, as distinct from the regular ignorance about their trading

---

[33] For the sake of completeness, it should be mentioned that, with the "improvement rule" alone, the above-mentioned minimum time for previous quotations to remain standing was dropped (cf. Williams [1980, 238f]), whereas the "rank queue" institution was actually combined with the non–binding requirement that subsequent price quotes *ought to* be always on better terms than the outstanding one (cf. Smith and Williams [1983, 177f]).

[34] Hence, in the appendix we use the abbreviation "HH 1, (2)" in order to characterize the type of experiments where the second proposition of the «Hayek hypothesis» plays a relatively minor rôle, whereas testing the first and the second aspect of the «Hayek hypothesis» on equal footing is referred to as "HH 1, 2" (e. g. Forsythe et al. [1982]). The inverse, "HH 2, 1", is restricted to experiments where the experimenters' *main* interest lies with testing a market's capacity to cope with additional degrees of uncertainty, rather than to extend the basic design of previous work to multi–seasonal or multi–period settings.

partners' or their competitors' preferences.[35] Put differently, experimental efforts during the last decade were mostly directed towards running "securities" markets, as distinguished from the former commodity markets, and towards testing the second aspect of Hayek's original hypothesis.

Plott and Sunder [1982] were first in moving explicitly to information aggregation in laboratory double auction markets for securities, i. e. for assets with state contingent payoffs. Participants were no longer split into distinct groups of buyers or sellers but all of them were "traders" now, with the power to buy and sell at the same time. After some initial training rounds, information about the randomly chosen state of nature was given to some "insider agents" whose number and identity was not revealed to other participants. As a consequence, the authors' chief interest was in whether prices, in spite of such *asymmetric information*, would adjust to a level which revealed the true state of the world to the uninformed individuals, and whether markets would lead to efficient allocations with respect to the differing dividend schedules of several trader "types". Building on «rational expectations theory», Plott and Sunder were able to assess their results more formally in the light of competing models of security behaviour: According to the alternative assumptions that traders would (a) exhibit "perfect foresight" (that is, act on "fully revealed" rational expectations), or (b) show "naïve expectations" and stick to "prior information" without updating their beliefs on price conveyed information, they formulated two complete sets of

---

[35] Friedman et al. [1987, 351f] propose a helpful distinction between this kind of ignorance and what is usually termed "uncertainty" in both theoretical and experimental literature: Since traders with private knowledge of their own dividend schedules, or preferences, never know at first what prices will be available to them, there is some endogenous type of "market uncertainty" inherent in any competitive market. Additional (exogenous) types of what they call "event uncertainty" or "insider uncertainty" occur only on securities markets where dividends on the traded assets are state contingent and, eventually, some traders are informed about the actual state of the world in advance.

price, profits and allocations predictions as benchmarks for the interpretation of actual market outcomes. Generally, the rational expectations predictions clearly outperformed those of the prior information hypothesis in explaining experimental results whenever the respective equilibrium values differed. Hence, evidence indicated that all available information was successfully aggregated, or that Hayek's claim on competitive markets' efficiency could be said to hold even under more complex conditions.[36]

Real–world security markets are characterized by two important dimensions. With their 1982 experiments, Plott and Sunder focussed exclusively on the dimension of uncertainty, leaving the second dimension, *time*, to a complementary study by Forsythe et al. [1982]. The latter concentrated on the time aspect by establishing a double auction market designed for multi–period assets but lacking any additional uncertainty. Actually, they were the first to establish the more flexible design of a trader market without predetermined roles for participants. Trading incentives were therefore created by assigning different payoff schedules, or preferences, to several trader types whose payoffs remained private knowledge.[37] With respect to earlier research, it is not much of a surprise that the experimental results again showed strong and rapid convergence of prices and quantities towards perfect foresight price levels and towards efficient

---

[36] It is worth mentioning that this was to the authors' surprise because they initially favoured prior information predictions as forecasts of trader behaviour; cf. Plott and Sunder [1982, 665]. However, later work strongly confirmed that any alternative approach, such as prior information or "maximin", could serve at best to explain the *starting point* in the dynamic processes of forming rational expectations; cf. Plott and Sunder [1988, 1090].

[37] In a later experiment, Smith et al. [1988] showed that differing individual preferences are not a necessary condition for trading activities to occur. But in a security market without any prior information about the actual state of nature, such design (in most cases) leads to bubbles which are followed by crashes during the price adjustment process (cf. King et al. [1993] for more recent evidence).

after trade allocations. Additionally, the market process appeared to be substantially accelerated if the sequence of distinct spot markets in each period was replaced by *futures markets* for later periods' asset holdings—a presumption from the 1982 results that was later confirmed by the same authors (Forsythe et al. [1984]).

On the basis of the piloting work done by Plott and Sunder [1982] and by Forsythe et al. [1982], there is a wealth of further studies which combine features of the two complementary designs and extend the experimental set–up to additional complications. Rational expectations hypotheses were shown to correspond best to price dynamics and allocations as generated by securities markets for multi–period assets with or without insider information and, eventually, with futures markets (Friedman et al. [1984]). This turned out to hold, even if insiders were randomly chosen from one period to another, thus precluding that uninformed individuals would simply guess the identity of insiders rather than adopting price–conveyed information from the market only (Banks [1985]). Things were no different when the security trade was no longer held orally—which it had been so far—but was computerized; when insider information was transmitted sequentially, instead of simultaneously; or when the content of information was no longer homogenous in that all insiders received either "good" or "bad" news but differed across trader types (Copeland and Friedman [1987]).

The next significant move in the evolution of experimental design is marked by Plott and Sunder's [1988] work: They tested information aggregation in a (single–period) securities market where *information* about the underlying state of the world was not asymmetric in the above sense but *diverse* in that all traders privately held different pieces of information, whereas the market as a whole was completely informed. For reasons which ultimately remain unknown, the markets

with this basic design generally failed to meet rational expectations price predictions and apparently lacked efficiency.[38] With some alterations, however, the authors were able to show that information aggregation was successful if either the single compound security was replaced by a complete set of state contingent claims, or if the traders' preferences were equalized by paying identical—i. e. only state contingent—dividends to all trader types. The result, with a complete set of "Arrow–Debreu securities", comes as no surprise. The authors concluded that some knowledge of other agents' preferences might be crucial for the operation of rational expectations principles in the diverse information environment. This mere conjecture was confirmed by Forsythe and Lundholm [1990] who in an otherwise identical market, instead of equalizing dividends across traders, made the differing payoff schedules common knowledge. Furthermore, they required all of their traders to participate in the experimental markets more than once, thus ensuring that they gained some experience with the present setting.[39] Hence, given some additional, but not too artificial qualifications of the informational structure, the case of aggregating information in security markets can be expected to be met by the competitive behaviour of all the agents involved.[40]

---

[38] To be precise, efficiency was poor if measured by the proportion of the extracted gains from trade to the maximum possible gains. Rational expectations predictions about after trade allocations of assets and about profit distribution seemed to hold, though.

[39] In another series of markets, Forsythe and Lundholm even rotated payoff schemes between trader types, so that each became familiar with the all schedules in use. But with otherwise experienced traders and with common knowledge of dividend schedules alone, this turned out to be unnecessary to achieve fully revealing rational expectations outcomes.

[40] Obviously, aggregation of partial and heterogenous information is not an easy thing to accomplish. But with the exception of O'Brien and Srivastava's [1991] article, there is no report in the literature which may be regarded as unambiguous counterevidence to the above claim. For reasons to be discussed in the appendix, we attribute the failure of

The final step towards testing the «Hayek hypothesis» in its full ramifications was made by Copeland and Friedman [1991] and by Sunder [1992]. Both move to examining double auction markets for single–period lived securities where recipients of relevant information are no longer determined exogenously and information is no longer costless. Copeland and Friedman build extensively on their own 1987 design, but in about half of their (computerized) markets, there is a sealed bid auction for advance information on the actual state of nature before security trading opens.[41] Sunder reports on two series of (both computerized and oral) security markets which all involve a market for information. In his "series A" markets, traders are invited to submit sealed bids for the purchase of information, which corresponds to the Copeland and Friedman design: A fixed number of individuals—i. e. the three or four highest bidders, respectively—receive a message enclosing hard information about the true state of the world at a uniform price (equal to the fourth or fifth highest bid) which is then made common knowledge. In Sunder's "series B" markets, the price of information is fixed, instead; it is publicly announced at the beginning of each trading period, whereas the number of traders who have actually bought information is not always disclosed.[42]

By making the process of acquiring information endogenous to their experimental design, Copeland and Friedman, as well as Sunder, are—to the best of our knowledge—the first to investigate under laboratory conditions the third proposition which is contained in the

---

their multiple assets, multi–period experiment to some idiosyncratic features of its informational structure and of the trading rules which they established.

[41] In a further contribution, Copeland and Friedman [1992] concentrated exclusively on the markets with endogenous information acquisition; however, referring to game theoretical concepts, they simply apply another tool to assessing the identical data.

[42] For obvious reasons, the identity of the traders who have purchased information is never revealed.

«Hayek hypothesis». By setting up our «Passau political stock market», we are trying to *focus* on examining *competitive information acquisition*.[43] Therefore, bearing in mind some natural, but fundamental, differences between laboratory environments and field studies, the results of Copeland and Friedman [1991] and Sunder [1992] are at the core of our interest in the evolution of experimental economics.

At first glance, however, evidence from the laboratory is not quite clear cut. In both of the fixed supply of information experiments, *asset* prices converge to fully revealing rational expectations levels, as they have done ever since. According to Copeland and Friedman, though, after trade allocation of assets and, above all, the prices and allocation of the *purchased information* generally conform with only "partially revealing" expectations predictions. Sunder, on the contrary, reports that his "fixed number" markets correspond to fully revealing rational expectations forecasts at a statistically significant level: the price of information drops "close to" zero, as theoretically stated by Grossman and Stiglitz [1980], while the securities market—in terms of asset prices and after trade allocations—converges to the fully rational expectations equilibrium. As a consequence, the distribution of net profits (i. e. net of cost of information) across traders tends to be equal.[44] Closer scrutiny of the Sunder [1992] findings, however, suggests that he may have exaggerated the degree to which the experimental data, as generated

---

[43] For a further discussion of this claim, see section 3.

[44] Following Sunder, it is rather the "series B" markets (with the price of information fixed) where asset price dynamics and trading activities correspond to predictions of a "noisy" rational expectations model, as distinct from fully revealing expectations forecasts. There, the number of traders who actually purchase information shows no tendency towards zero; asset price convergence is much more erratic; and net profits of the informed are statistically indistinguishable from those of the uninformed.

by his series A markets,[45] correspond to strong–form efficient rational expectations hypotheses: there is clearly a leftward shift in the demand for information, but prices do not drop significantly closer towards zero than they did with Copeland and Friedman [1991]. In spite of the markets' efficiency, as indicated by security prices and other data, there must be some "noise" in the double auction trade, which preserves a sufficient incentive for some traders to engage in information acquisition activities and, in turn, allows them to recover their cost of doing so.

Hitherto, we have omitted the Forsythe et al. [1991, 1992] contributions on the «Iowa political stock market» (IPSM)—an experiment which was actually conducted in 1988. It was this that ultimately inspired us to engage in similar work at Passau University. We did this not only because we wished to proceed chronologically in our review,[46] but, above all, because a "political" stock market, although its design owes much to previous experimental work, represents a fundamentally new type of experiment: Rather than being a laboratory test, markets like the IPSM come very close to testing the «Hayek hypothesis» in a *field environment*. In the experimental literature, some authors emphasized the main feature of laboratory work as being the experimenter's *control* of both the incentive structure and the informational situation of all participants: private valuations are created by assigning (different) dividend schedules to all participants, the arbitrary commodities or securities having no significance of their own to subjects who were recruited

---

[45] In fact, their number falls to one and a "half" markets (out of seven), or to a total of 20 trading periods, respectively. Hence, Sunder's main interest seems to have been with the "fixed price" markets, which differ more from Copeland and Friedman's 1991 design.

[46] Note that the experiments Sunder [1992] reports on were actually run between 1983 and 1986; in Copeland and Friedman's 1991 article, there is no corresponding not,e but their first working paper on the respective tests dates back to 1988.

for the laboratory tests.[47] The distinction between private and common knowledge—which is perfectly drawn by private communication vs. public announcement of relevant information through the experimenter—is essential for setting up distinct tests on the aggregation of "asymmetric" or "diverse" information or on information acquisition, respectively.[48]

The main difference between laboratory markets and a political stock market can therefore be seen in the *non–artificial informational situation* to which participants are exposed: there is no impartial observer able, a priori, to distinguish pieces of relevant or true information from any "noise". Moreover, even the experimenters do not know beforehand if information available to the market as a whole can be said to be collectively complete. Things are slightly different with respect to the *incentive structure* which governs the participants' trading activities in political stock markets: in establishing a reward system which is similar to those used in laboratory experiments, we are relying for a successful forecast of election outcomes, above all, on traders who condition their behaviour first and foremost on monetary incentives.[49]

Nevertheless, we are aware that with a political stock market, the whole question of *judgement biases* arises which may be due to political preferences or some demographic characteristics of the trader population. Hence, in addition to the economic background of

---

[47] Cf. Smith [1976a] who states that "control is the essence of experimental methodology (275)".

[48] This is particularly stressed by Friedman et al. [1984, 350], O'Brien and Srivastava [1991, 1818], and Copeland and Friedman [1991] who pointed out that "laboratory asset markets are a natural setting to study the issue of market efficiency because private information can be controlled... (265)".

[49] By a rather straightforward mechanism which is to be explained in section 3, equilibrium stock prices at a political stock market can be interpreted as a forecast of a given candidate's, or party's, prospects for his or its fraction in popular votes.

experiments like the IPSM or the one we are running in Passau, related research in the political sciences and in psychology might deserve some attention if experimental data is to be assessed appropriately. As a matter of fact, Forsythe and his colleages devoted considerable efforts to detecting the influence of possible biases on the trading behaviour of their sample and on their market's outcome. The results were generally negative: there was no statistically significant impact arising from sample characteristics, such as sex, race, or income class, on trading behaviour. And although they clearly observed judgment biases according to political preferences, the market's forecast of election results was almost perfect.[50] Therefore, by means of additional surveys and various additional ways of assessing our data, we are well prepared to deal with such issues if our findings suggest the need to do so. However, we do not expect this to be of particular interest.

Finally, note that unlike in all previous laboratory experiments, on a political stock market participants incur the *risk of making real losses*. This may help to discipline "irrational" or "ideological" traders to some extent.

As a consequence of the complications we have just mentioned, subjects in a political stock market face noticeable difficulties in identifying reliable information and turning it to their own profit. In spite of these peculiarities, *voluntary participation* can be expected to be much higher than in laboratory tests. Most of the experiments which we reviewed earlier in this section involved no more than 20

---

[50] Forsythe et al. [1992, 1157–1159] attributed this to what they called the "marginal–trader hypothesis" which hinges on the simple argument that results on judgement biases refer to the *average* trader, while prices are determined by *marginal* traders. For political preferences and demographic characteristics of their sample, as registered by several waves of additional mail surveys, cf. Forsythe et al. [1991, 11–13]; for the results on (non–)biasedness of trading behaviour according to these features, see iid. [1991, 28f and 1992, 1153–1156].

individuals. The IPSM finished up with a total of 192 traders.[51] During the first few weeks of the experiment we are running in Passau, the number of participants quickly rose to 150.[52] Perhaps the task of forecasting an election outcome could be regarded as a perfect opportunity to test competitive information acquisition empirically—with regard both to its inherent complexity and to the natural interest of potential traders in the question at issue.

To summarize the ideas discussed in this section, we still have to address one question: with respect to both the theoretical reasoning and the experimental experience of the past decades, how can we expect a "political stock market" to succeed in forecasting such a thing as an election outcome? Stated differently, what can be said about the relevant information that needs to be aggregated, and about the—perhaps fragile—incentives that exist to acquire and to introduce them to the market? Three points need to be made.

- First, much of the information required for successful participation in the market and, hence, for the stock prices to be reliable as a forecast may be gathered by the participants accidentally and, moreover, *costlessly*—simply in the course of their usual activities. Given this, the whole conflict between stock market equilibrium and the dynamics of information acquisition disappears.[53]
- Second, the establishment of a political stock market differs from laboratory tests in that gross profits (i. e. gross of information costs) which are accumulated on the traders' cash account are much easier to observe than net profits—for experimenters as

---

[51] Cf. Forsythe et al. [1992, 1145f].

[52] Since we set up two parallel markets (see section 3) with some, but not all, traders engaging in both our experiments, these figures are not now perfectly comparable. In a later publication on our results, we will be more careful on this point.

[53] Cf. Grossman [1981, 556].

well as for the participants. Thus, even if information is not, or not entirely, costless, some individuals may not be fully aware of such costs. However, this assumption does not necessarily imply that, in sharp contradiction to our theoretical foundations, we must expect our traders to be myopic or irrational. In their perception, the (non–monetary) cost of information may be *outweighed*, in a sense, by other sources of utility which they draw from participating in a political stock market: e. g. interest in gambling, politics, or economic research; being part of a distinct group of "stock market freaks", and so on.

- Finally, the structure of information on a political stock market is not a simple one and is certainly not homogenous. If, therefore, traders engage in some informal "division of labor" in the use of available, or rather the creation of, information, as a natural result of an environment with asymmetric (partial) information, the incentive to bring forth additional knowledge and to go on trading could be sufficiently preserved. In any case, the whole theoretical discussion about some degree of *heterogeneity*—in beliefs, tastes, endowments, and opportunities to produce information—which may be necessary for arbitrage activities to occur and for equilibrium prices to be achieved applies.[54]

Note that in both of the laboratory tests involving information acquisition, the security prices (which correspond to the stock prices we are relying on as our forecast) showed convergence towards fully revealing rational expectations levels, even if after trade allocation of assets or endogenously determined prices of information appeared to be somewhat misguided.[55] This might be regarded as some, albeit

---

[54] Cf. Working [1958, 192f], Grossman [1977, 440–442], Wihlborg [1991, 299f], Madhavan [1992, 612].

[55] Admittedly, Sunder [1992] reports on some of his (fixed price of information) markets arriving at "wrong" prices, i. e. at prices which correspond to a wrong state of nature. The significance for our setting must not be overestimated, though: In most of

weak, support for our contention that the "no–information" case is no equilibrium in competitive information acquisition and aggregation, and for our tentative claim that competition in a field environment balances the use of all available strategies in order to solve the central problem—here: to value a party's election prospects correctly—that individuals face at a given instance.

3. »Passauer Wahlbörse«: Variations in Experimental Design

In 1994, Germany will see a total of 18 elections[56] at various federal levels, culminating in the general election to be held in October. A multitude of political parties, some of which only emerged in the course of the last few months, are competing in these elections, with different parties running for different elections. Moreover, Germany's political climate appears to be somewhat volatile in the aftermath of the country's reunification; thus, there may well be the potential for a landslide in one direction or the other.

This creates a truly excellent stage for a political stock market—a tough job for speculators and the «Hayek hypothesis» alike. Motivated by this opportunity, we launched the »Passau Political

---

these cases, all informed traders after selling their (fixed) initial endowment of assets became inactive, and the uninformed who were trying to gain an informational free–ride—or "the blind leading the blind"—came to a wrong conclusion. In a political stock market, however, the cost of information, if any, should be expected to increase commensurate to the efforts made to collect or create it. Furthermore, there is certainly no limit to the number of participants who hold or acquire "better" information throughout the market's opening time, nor is there any constraint on the number of portfolios or stocks a single participant may buy and/or sell.

[56] Not counting the presidential election. The Bundespräsident is not elected by popular vote; instead, this decision is taken by a national assembly that consists of delegates from various legislative bodies.

Stock Market« (»Passauer Wahlbörse«, referred to as PWB in the remainder of this article) in January 1994. This experiment encompasses two parallel markets, one for the Bavarian state election and one for the general election, where party stock can be traded. Instead of merely enlarging the existing database, however,[57] we opted for a slightly different experimental design.[58] This section is devoted to explaining the differences and discussing—although rather briefly—why our experiment appears to be interesting in its own right.

For readers who are as yet unfamiliar with the fundamental design of a political stock market, however, we commence with a short sketch of the basics (in which we follow Forsythe et al. to a considerable degree). The PWB consists of two organized markets where party stock can be traded.[59] Each share entitles its (final) holder to receive a dividend that depends on the election outcome. For simplicity, one share in party X will pay 10 Pfennig (i.e. a tenth of a Deutschmark) for each percentage point of the popular vote this party manages to obtain in the respective election. Thus, stock prices can be translated into predicted vote shares by simply multiplying them by 10, and the

---

[57] Which is now quite broad. Quite apart from the renowned IPSM operated by Forsythe et al. in 1988, this group has—in collaboration with local researchers—organized several other markets in Denmark, Finland, Turkey, and Germany (see Forsythe et al. [1992, 1157]). The German markets were run for the 1990 Bundestag election, the first German general election to be held after reunification.

[58] In a few weeks' time, a political stock market with the original institutional design developed by Forsythe et al. will commence operations at the Universität Regensburg, Passau's neighbouring university. As the student populations of the two universities are rather similar demographically, a comparison of results may prove particularly interesting.

[59] Due to legal quibbles, only university members are allowed to participate in our experiment. In fact, organizers of political stock markets seem to face the same legal hassle all over the world (see Forsythe et al. [1991, 7]).

PWB has a "resolution" of 0.1 percentage points, the same as the official election results.[60]

We, wearing our banker's hat, sell "complete" portfolios consisting of seven shares—a single share in each of the six most important parties running for an election and one share in the "rest of field"[61]—to participants for 10 Deutschmarks. This means that the PWB, as a whole, is a zero-sum game.[62] There is no binding limit[63] to the number of portfolios a traders can acquire, and fresh portfolios can be ordered at any time. Moreover, we are prepared to buy back at any time any number of "complete" portfolios for 10 Deutschmarks.[64] In addition to the portfolios they hold, traders are required to have a cash account with an initial deposit of 10 Deutschmarks for each market they want to participate in. This cash account furnishes the liquidity for their political stock market operations. We do not lend traders money, and short sales are disallowed. It is possible for existing traders to inject additional funds into the PWB, although we have limited their opportunities to withdraw money from the experiment.[65]

---

[60] Note that because a tenth of a percentage point corresponded to 0.25 cents in the IPSM, the results of Forsythe et al. bettered the design precision of 0.4 percentage points (see Forsythe et al. [1992, 1143f]).

[61] A complete Bundestag portfolio encompasses one share in each of the following parties: CDU/CSU, SPD, F.D.P., Bündnis 90/Die Grünen, Republikaner, PDS (the former East German SED), Rest of Field. For the Bavarian election, we have included the following parties: CSU, SPD, F.D.P., Bündnis 90/Die Grünen, Republikaner, ÖDP, Rest of Field. We have elected to include those parties that, on the basis of the results of the 1990 elections, stand a chance of winning more than 2% of the vote.

[62] If we disregard interest foregone, that is.

[63] To avoid unpleasantness, we have restricted an individual's maximum PWB investment to 1000 Deutschmarks. Up to now, individual accounts are not even getting close to this limit.

[64] This is intended to allow some minimal arbitrage operations. Due to the sluggishness of the PWB, however, no actual arbitrage opportunities can arise (see below).

[65] This is because our university's administration was reluctant to handle "premature" withdrawals, except in cases of dire need.

Trading can only occur through us (we're wearing our broker's hat now). Unlike previous experiments, however, our markets are *not* organized as computerized double auctions; instead, we opted for a *call market* modelled on the institutions of the "Kassamarkt" at the Frankfurt stock exchange. There is a single trading day per week.[66] Bids and asks must be submitted in writing and are subjected to severe feasibility tests: A trader's portfolio must contain, ex ante, all the shares (s)he has put up for sale, and his/her cash holdings must be sufficient to buy all stock ordered at the trader's outside bid. After those checks have been completed, we take the admissible bids/asks and set stock prices so as to maximize the number of (voluntary) trades, given traders' offers. Obviously, this boils down to the competitive market of basic textbook microeconomics—we use the feasible bids and asks to derive supply and demand schedules, the intersection of which determines the equilibrium price.[67] All feasible trades are executed at the equilibrium price, which is disclosed to the traders (together with information regarding their individual portfolios and cash balances). After this, the market starts afresh.

As you will probably have relized by now, the PWB differs from similar experiments in three ways:

- The German "Superwahljahr 1994" provides a much richer setting than the elections that have been used previously (the German election in 1990 comes close to, but cannot quite rival, the amount of information traders need to process);[68]

---

[66] This, of course, is for our convenience only. Frankly, we do not have the resources to run our markets more frequently.

[67] As PWB shares are not perfectly divisible, there is a need for some conventions to govern price determination when there is no unique equilibrium, and to govern the allocation of shares when there is excess supply (demand) at the equilibrium price. The first difficulty is solved by taking the arithmetic mean of the marginal prices, in the second cases, we resort to the usual rationing by the shorter side of the market.

[68] Unfortunately, (to the best of our knowledge) neither Forsythe et al. nor their German collaborators have published their 1990 German results.

- Participating in the PWB does not presuppose access to a computer terminal, nor does it involve dealing with the intricacies of a computer network;
- Most importantly, the PWB is organized as a call market.

Let us consider each of these differences in turn.

In order to succeed in predicting the vote shares of the various parties correctly and, ultimately, to make money, traders on a political stock market may use information from a host of sources: newspaper articles, public opinion polls, conversations with friends and acquaintances, history, arguments overheard in bars, preceding elections, to name but a few. The signals obtained from these sources, however, are tainted with noise, which requires agents to filter the available information. The more information there is and the more diverse this information, the more formidable the traders' task becomes, and the less chances of success we expect the «Hayek hypothesis» to have. Furthermore, falsification of this hypothesis appears the more likely the more parties vieing for power are included in the experiment and the more unstable the political environment in which it is performed. The German "Superwahljahr 1994" is exemplary in all these respects. The PWB has been started early enough to capture the impact of all the elections held in 1994, and it covers two elections at different federal levels and with different initial conditions.[69] For these reasons, data from the PWB promises further insights into what pieces of information individual traders condition their decisions on and what pieces they deem irrelevant.[70]

---

[69] The Bavarian electorate is generally considered to be fairly conservative, and the CSU enjoyed a comfortable majority during the last decades, although this majority has eroded somewhat since the days of Franz Josef Strauss. At the federal level, things appear much less clear cut a priori.

[70] We intend to support the internal evidence by several additional surveys. A questionnaire dealing with basic demographic properties and party leanings is handed out, and filled in, on traders' first registration with us. Others will follow. Although we

The previous political stock markets relied rather heavily on computerized academic environments. As a rule, traders had to log into a computer network in order to advance bids and offers. A central computer recorded these offers and processed them to determine the current market price of each brand of party stock, and it supplied price information to authorised persons (who knew the password) on request.[71] We did not feel at all happy about adopting this modus operandi at the Universität Passau. First of all, quite a lot of students over here do not have access to the computer network, mostly because they do not bother to apply for it. Additionally, computer literacy seems to be distributed unevenly over the various faculties. Since we intend to attract participants from all of our university's departments, a completely computerized experiment did not appear to be a viable proposition.[72] Also note that this "paper approach" eliminates a possible source of extraneous motivation to engage in trading activities: Williams [1980, 245] points out that fiddling with computers and communicating over a computer network provided some of his initial subjects with incentives to enter premature bids. As traders were committed to offers in his system, this might have accounted for the failure of some of his initial experiments.[73] Smith [1982, 170] found computer literacy to be a necessary prerequisite for success of the «Hayek hypothesis» in a computerized experimental environment. All the same, we cannot feel smug about the "paper approach" just because it removes some

---

do not ask our participants for their names and addresses to preserve anonymity, we still accumulate enough data to link individual traders to questionnaires. This will enable us to perform simulation runs of our markets with subsets of the trader population removed.

[71] See Forsythe et al. [1991 and 1992] for a description of how this was done.

[72] We do use a computer to calculate equilibria and for accounting purposes. Because we do not require our computer to be a network server and because there is only a single trading day with simultaneous offers, our software runs on an IBM clone with a venerable 386SX processor clocked at 16 MHz.

[73] See section 2 and the appendix for further remarks.

incentives other than monetary rewards and thus helps to induce carefully designed utility functions (see Smith [1976a]). Political stock markets differ from the usual laboratory experiments in that they gain a lot of momentum from people's—especially students'—interest in elections, and we are unable to rule out, a priori, the possibility that people join the experiment and deal in party stock for other reasons than to make profits. Traders' motivations are all the more suspicious because the PWB is, strictly speaking, a negative-sum game if we take the interest foregone on PWB investments into account.

The chief difference between the PWB and its predecessors lies in the choice of market institutions: On designing our experiment, we replaced the double auction mechanism with a *call market* mechanism. There are three sources of additional interest afforded by this form of experimental organization: First, there is a current debate on whether stock market institutions based on the double auction principle ought to be supplemented by a call market or not. The theoretical case for a mixed system[74] rests on the contention that call market elements (a) lend *stability* to an otherwise volatile market and (b) can operate under conditions of *market thinness*.[75] Although this is not our primary field of interest, PWB results may be of some help for researchers in this area.

Second, running a call market enables us to study *information acquisition* and *aggregation* aspects in comparative isolation and to accentuate possible conflicts between the static and the dynamic parts of the «Hayek hypothesis». The first proposition we included in our statement of this hypothesis is guaranteed by our market institutions—more specifically by our stockbroking activities—while the conventional stock market design entails an implicit testing of this "original Hayek hypothesis" as stated in Smith [1982], as well. Also,

---

[74] Note that the Frankfurt Stock Exchange uses such a mixed system.

[75] For a detailed analysis see Madhavan [1992].

it seems fair to say that dynamic information acquisition, if it requires us to gainsay static efficiency (as the standard argument has it), may be impaired under call market rules.

This leads us to our third point: For several reasons, there is a very real probability that the «Hayek hypothesis» may not fare as well on a call market as it does on a double auction market. Note that in the latter system trading may occur at inframarginal prices, which enables informed agents to recoup at least some of their outlay on information acquisition,[76] whereas *inframarginal trades are precluded* on a call market. Furthermore, such a market—especially if run only once a week—appears rather sluggish in comparison to a *continuous time* double auction.[77] More precisely, the former is of time-discrete nature, which does not allow actual arbitrage operations to be carried out.[78] The mere spacing of trading days may also erode the market value of fresh information as novelties are conveyed through other channels than market prices. Finally, our rigorous feasibility checks impose further restrictions on the realm of possible market operations. For example, agents are unable to finance stock purchases with the proceeds of the same week's stock sales, which hampers them when re-allocating their portfolios. Taken together, these problems may well imply that the «Hayek hypothesis» has less chances of success in our experiment than in the previous studies.

---

[76] See, for instance, Sunder [1992, 689]

[77] See again Madhavan [1992].

[78] We do have some facilities for what might be called "pseudo-arbitrage". When the market value of a "complete" portfolio exceeds 10 Deutschmarks—as it did on both PWB markets in the first few weeks—, traders may order fresh portfolios from us (at 10 Deutschmarks, or 100 percentage points) and try to sell them on the next trading day at the current market prices. Casual evidence shows that this opportunity was seized by a substantial number of traders, who managed to make some profits in the process (one trader reported a weekly return of 5% on his PWB investment, gained entirely in this fashion). However, this is not "real" arbitraging because trading is carried out at the subsequent week's prices instead of the original "excessive" price vector. Evidently, this operation is not riskless. Note that the inverse operation (buying complete portfolios for resale to us) is also possible.

There is, however, an upside as well. When markets are very thin (see above), a continuous time double auction may lose much of its appeal and may, in extreme cases, even cease to function. As political stock markets face notorious market thinness problems in off-term time,[79] having a robust system of market institutions may turn out to be a positive boon after all.

At least to our thinking, this makes for enough open questions and gaps of evidence to justify our research. We sincerely hope that the results of the PWB experiment will contribute to the understanding of the «Hayek hypothesis» and of its limitations, as well as to providing new evidence on the rôle of (stock) market institutions.

---

[79] Cf. Forsythe et al. [1991, 10]. The German two-term academic year engenders much longer off-term periods than its American (or English) three-term counterparts. Less than 60% of our PWB trading weeks fall into the winter and summer terms. Although trading subsided after winter-term lecturing ceased on February, 28, the PWB has but in a single instance failed to quote a stock price.

Appendix: Experimental tests of the «Hayek hypothesis»

—Scheme of our review:—

Author(s) and reference	
Test on...[*] type of experiment # of participants	Comprehensive description of experimental design Summary of main *<u>results</u>*

Smith [1962], Experimental Study of Competitive Market Behavior

Revelation of information [HH 1] laboratory tests by oral double auction commodity markets #: 21–43

In this early study, the author reports on a series of *pilot experiments* which still are conducted without introducing monetary rewards, or payoffs, for "successful" participants. They are meant to test some of the hypotheses of neoclassical microeconomics. In each experiment, there are two groups of assigned "buyers" and "sellers" whose individual valuation for the traded is good is strictly private knowledge. Thus, the (stationary) supply and demand schedules of each market—with different slopes and, hence, different proportions between sellers' and buyers' rents—are unknown to the participants. Each seller initially holds one unit of the traded good but there are several "days", or periods of trade, in each market. In some of the markets, after a few replications, demand or/and supply schedules are shifted once.

<u>Results</u>: Generally, contract prices show a strong and rapid tendency towards competitive equilibrium levels in all of the experiments. Efficiency is measured by a (constantly decreasing) coefficient of convergence which is computed for

[*] Here, we use the abbreviations "HH 1 to 3" in order to relate the reported experiments' main intentions to the three aspects of the «Hayek Hypothesis» as distinguished in section 1.

each trading period and by the (very small) number of "submarginal", or extramarginal, traders who actually succeed in making contracts.
In the simple settings with both normal supply and demand schedules, the «Walrasian hypothesis» (the rate of increase in market price is an increasing function of excess demand at that price) seems to hold. In other cases—e. g. when supply is perfectly elastic—, price behaviour leads the author to build up an alternative explanation which he calls the «excess rent» hypothesis, relating the "speed" of contract price adjustment to the excess of buyers' plus sellers' virtual rent over the cumulated equilibrium rent. Analysis of the experimental data gives some support for this new hypothesis (cf. Smith [1965]).

Smith [1964], Effect of Market Organization on Competitive Equilibrium

Revelation of information [HH 1]
laboratory test by oral bid or ask auction commodity markets
#: 20–28

The idea of testing the effects of market organization on competitive equilibrium stems from one of the 1962 series of experiments where trade was organized as an ask auction market, as distinct from the double auction institution in all other markets. Here, the author establishes two series of tests in which different groups of participants, according to identical supply and demand schedules, are invited to trade under three *differing institutional settings*: First, only sellers are permitted to make offers, whereas buyers are only free to accept them (ask auction); secondly, there is an ordinary double auction market with both sides free to make asks and bids; and finally, only buyers are permitted to make offers (bid auction).

Results: The results generally correspond to the author's initial presumptions: Speed of convergence of contract prices towards competitive equilibrium level is much higher under the double auction rules, and prices on one sided auction markets tend to persist at levels above (below) the equilibrium price when only sellers (buyers) are permitted to make offers. This is because sellers (buyers), forced to lower (increase) their price quotations by competitive pressures, are revealing more information about the prices at which they are willing to contract than are buyers (seller). Thus, regardless of whether initial contracts—without any observable regularity—are made at prices above or below the equilibrium level, the inactive market side learns that by waiting they can take advantage.

Smith [1965], Experimental Auction Markets and the Walrasian Hypothesis

Revelation of information
[HH 1]
laboratory test by oral double auction commodity markets

#: 24–30

Smith's 1965 experiments are intended to provide a more rigorous comparison of the «Walrasian hypothesis» and his tentative «excess rent» (e. r.) hypothesis, as stated in 1962. Therefore, he intentionally establishes rather *unconventional demand and supply schedules* which are both perfectly elastic at different price levels, one of them rationing the number of possible contracts and the other exhibiting different quantities of excess supply. Thus, in full competitive equilibrium, the entire rent in these markets must accrue to buyers.

Results: In spite of earlier results, contract prices show a strong tendency to converge to the competitive equilibrium level which corresponds to theoretical predictions. Obviously, this tendency is an increasing function of the quantity of excess supply (e), so that in markets with a comparatively small e, price behaviour still resembles the 1962 data. With respect to his major analytical purpose, the authors finds strong support for his e. r. hypothesis against the Walrasian hypothesis by some regression estimates. It should be noted, though, that the e. r. hypothesis—having a distinct intuitive appeal under the present experimental design because each seller facing the danger of foregoing some potential rent at $p > p^S$ tends to break any tacit co–operation—becomes observable only in laboratory experiments. Finally, from some pilot sessions which were made with cash payoffs paid only to a randomly chosen subset of participants, the author concludes that market behaviour and, hence, experimental results differ significantly between full and random rewards.

Smith [1976b], Bidding and Auctioning Institutions: Experimental Results

Revelation of information
[HH 1]

laboratory test by commodity markets under various institutions

#: 22–37

The main task of this article is to review earlier work in order to compare market behaviour under *alternative institutions*, such as double auction, ask or bid auction, posted offer markets, and sealed bid auctions. Therefore, the author reports on several previously unpublished experiments, especially with multi–unit trade where participants gain more experience during each single trading period. Besides that, the paper is particularly interesting in that it contains precise definitions of the market institutions under consideration and sums up ex-

perimental evidence on their relative performance, as to accomplishing competitive equilibrium.

<u>*Results*</u>: Typical results of experimental work which has been carried out so far are summarized in a sequence of propositions which, broadly speaking, are not news. When the significant efficiency features of laboratory double auction markets are compared to other institutional settings, it turns out that all alternative rules are less efficient in that price convergence to equilibrium level is much slower and prices often tend to persist at levels above or below equilibrium. Ask or bid auctions generally work to the disadvantage of the market side having the price initiative, whereas posted offer markets work to the advantage of price initiators because the other side is set to a take–it–or–leave–it position. In the case of sealed bid auctions, there is no meaningful comparison between contract prices or quantities and some respective equilibrium level, since supply is fixed. The only conclusion that can drawn from experimental evidence is that discriminative pricing generally leads to lower bids than competitive pricing where accepted bids are filled at the lowest accepted bid price does.

Miller, Plott and Smith [1977], Intertemporal Competitive Equilibrium: An Empirical Study of Speculation

Revelation of information
[HH 1 (2)]

laboratory test by oral double auction commodity markets with cyclical demand

#: 24

The authors move from testing aggregation of private information in a more or less stationary environment to examining markets with cyclical but unknown *shifts in demand*. Therefore, they conduct two experiments in which either buyers or specially assigned "traders" can buy season 1 supply in order to satisfy their own season 2 demand (with zero storage cost) or to resale it, respectively. In neither case, *speculators* know anything about future supply and demand or future market prices. Moreover, so called traders never have any information on individual or aggregate supply and demand. Both experiments are repeated for several periods each of which consists by identical seasons but there is no carry over of the commodity from season 2 to the following season 1.

<u>*Results*</u>: In both experiments, there is a tendency of contract prices towards the intraperiod price–quantity equilibrium in season 1 of period 1 which weakens in season 2 and during the following replications. After three periods, prices clearly converge to an intertemporal equilibrium level.

Market efficiency is assessed by a new measure, namely by the sum of actual consumer plus producer surplus, i. e. the sum of reward payments to participants, as a percentage of the maximum possible gains. Alternatively but without additional implications, it could be measured by the number of extramarginal units which are traded, or the number of intramarginal units which fail to be traded.
The fact that the second experiment which includes two traders who are exclusively permitted to speculate performs relatively worse than the first one is attributed to specific features of the participants' behaviour strategy and, hence, to sampling variations, rather than to the experimental design.

Plott and Smith [1978], An Experimental Examination of two Exchange Institutions

Revelation of information [HH 1]

laboratory test by one–sided oral auction and posted offer commodity markets

#: 8

The experiments reported here are meant to compare two different *trading institutions* in *multi–unit trade*: (one–sided) oral bid auctions vs. posted bid markets. The authors' intention is to relate earlier work by Smith on one–sided auctions to a previous study of Williams [1973] on posted offer procedures which seemed to contradict the results reported by Smith. Williams attributed this to the multi–unit case he had considered, as distinct from the single (or two) unit per trader experiments which had prevailed so far. The a priori expectation of the authors is that the distribution of prices in the former setting would dominate the distribution in the latter for reasons which were stated briefly in Smith [1976b].
Thus, they first replicate Williams' 1973 experiment and complete it with an otherwise identical oral bid auction. Secondly, they set up another twofold experiment which reflects some evolution of experimental design in general, with commissions paid for trading as such and some more minor alterations.
A new feature of the multi–unit trade is that individual buyers and sellers no longer are told a definite individual valuation for units of the traded good but rather hold an individual demand or supply scheme in which additional units have decreasing or increasing values, respectively.

<u>*Results*</u>: Broadly speaking, both price dynamics and the price comparison across the different institutions correspond to the authors' expectations: In both settings and in each of their markets, prices converge to competitive equilibrium level from below. In posted offer markets, though, convergence is slower, mean prices of each trading period are lower than in bid auctions, and the observed

degree of efficiency is somewhat lower, too. In the present paper which is really prior to Smith [1976b], the authors develop the efficiency measure which is used there, representing the extracted gains from trade as well as the fraction of maximum payments which actually has to be paid to participants. Hence, the results of Williams are shown to depend crucially on the posted offer institution he used, rather than on multi–unit trade.

Williams [1979], Intertemporal Competitive Equilibrium: On further Experimental Results

Revelation of information
[HH 1 (2)]

laboratory test by oral double auction commodity markets with cyclical demand

#: 12–14

The author's experiments are mostly an extension of Miller, Plott and Smith's [1977] work. In an environment with cyclical but unknown *demand shifts*, it is meant to compare a market with the opportunity of *speculation* by carrying over units of the traded commodity between seasons to an otherwise identical market with *autarchic* seasons. Therefore, sellers and buyers each are given marginal valuations for two units which differ across units, individuals and two seasons. Additionally, there are two "traders" in each market with the exclusive right to purchase in season 1 for resale (with zero storage cost) in the following season 2 but not for any further carry–over. These traders are kept completely uninformed about the underlying supply and demand schedules.

<u>*Results*</u>: The replication of a market with speculative carry–over shows rather similar features as the previous study by Miller, Plott and Smith. Applying the usual measures for speed of convergence of market prices to the intertemporal equilibrium level, and for market efficiency, the author attributes some details of the process to sampling variation but his results are basically the same. Additionally, he explicitly demonstrates the key role of traders for the reported outcome.

The comparison with an otherwise identical but autarchic market, i. e. without any traders, shows additional support for the interpretation of the former experiment: As buyers and sellers become familiar with the cyclical demand shifts in subsequent periods of trade, prices almost perfectly adjust to the different autarky price equilibrium in either season. Price convergence is much slower than in stationary tests, though, indicating that the cyclical shifts at first lead to cross–seasonal expectations which only gradually expire.

Williams [1980], Computerized Double–Auction Markets: Some Initial Experimental Results

Revelation of information
[HH 1]

laboratory test by computerized double auction commodity markets with and without shifts in demand

#: 16–20

The author reports on the first series of *computerized* laboratory tests ever, primarily designed to compare the results of automated trade to those of oral double auction, and to re–examine standard propositions drawn from experimental evidence so far, as summarized by Smith [1976b]. Additionally, the experimenters still were looking for appropriate institutions, as to modelling double auction in a computerized environment.
Therefore, the setup of the computerized markets differs with respect to the *rules* according to which price quotations are dealt with when there are outstanding bids or asks: Previous quotations (a) are automatically rejected after some minimum time for acceptance, and subsequent offers are not governed by any rules; (b) subsequent price quotes must progress so as to reduce the bid–ask spread but there is no minimum time for previous quotations to remain standing; (c) subsequent offers are queued according to the time of entry before replacing the current quotation which stands displayed to the market for the above minimum time. For reasons of programming simplicity, under (c) a participant cannot accept price quotes nor alter his own quotation while queued.

<u>*Results*</u>: The results of comparing an otherwise identical oral market to a computerized double auction using rule (c), at first, are not very encouraging: Price convergence in the automatic trade setting is much more erratic and far from being sufficient within a limited number of trading periods. However, participants run about three times as much offers per period than in the oral auction and apparently derive some (uncontrolled) utility from the mechanism itself. Hence, the failure of the experiment may be due to the non–satisfying queuing procedure.
A second series of tests is meant to compare rules (a) and (b) in simple stationary environments. In most of these cases, price convergence is better than before but still much slower than in oral double auction markets. The influence of rent asymmetries on price convergence, as observed by Smith [1962, 1965] in his first oral experiments, is significantly lowered under rule (b) which forces participants always to offer on better terms than the outstanding price quote.
With the coming up of computerized trading mechanisms the question of experiencedness of participants arises, at least as far as familiarity with the display of information and with the mechanical tools is concerned. Thus, with a final series of tests (using rule (b)) differences in trading behaviour between

inexperienced subjects and others who participated in a previous computerized markets are studied. The presumption that participants may require a training period to be adequately prepared to cope with computerized trade is generally confirmed, since the sequence of market prices starts to resemble those of similar oral auction experiments and statistical data on price convergence and efficiency are close to the "standard" results. As a consequence, difficulties with the first computerized experiments may not be attributed to the absence of some information other than prices—e. g. occasional moans or sighs, or multiple acceptance—which is public in oral auctions, although such occurrences actually are against the rules of experimental markets.

Smith [1982], Markets as Economizers of Information: Experimental Examination of the «Hayek hypothesis»

Revelation of information [HH 1 (2)]

laboratory test by computerized double auction commodity markets with static and cyclical demand

#: 7–12

The author reports on quite a number of experiments in *computerized* double auction markets all of which are meant to test if, how fast, and under which conditions, market prices for an arbitrary commodity would converge to competitive equilibrium level when information of buyers and sellers about their valuation or cost, respectively, is strictly private.

Efficiency of the markets is measured by the number of single units traded, as compared to the maximum quantity of possible transactions with given demand and supply schedules.

Convergence and efficiency are tested in both *stationary* and "*dynamic*" (with a one time shift in demand or supply, respectively, with cyclical demand, or with irregular shifts) environments.

Results: Like most of previous experimental evidence, the reported tests provide strong support for the «Hayek hypothesis», with a higher speed of convergence depending on the experience of participants, on trading volume and on the accuracy of price expectations built up in previous periods. Alternative, but in some sense weaker, hypotheses, like price–taking behaviour which requires a large number of participants, or the necessity of complete information, can thus be rejected, at least under laboratory conditions.

Apart from Smith and Williams's [1983] report on a significant improvement of the computerized double auction mechanism, the present paper, in some sense, completes the experimental work which has been carried out during the first two decades of experimental economics. So far, experimenters have mostly

concentrated on price convergence towards competitive equilibrium and on market efficiency in a more or less stationary environment. Participants were assigned to well–defined roles—as buyers, sellers, or traders, respectively—and were privately told specified preferences, or individual supply and demand schemes, regarding to the traded good.

There is no easy line to be drawn between Smith's [1982] experimental design, as far as cyclical demand or irregular shifts in demand are involved, and the following experiments in markets for multi–period lived assets. However, the relationship of the latter tests to those involving security trade, with state–contingent payoffs and additional degrees of uncertainty, induced by "asymmetric" or "diverse" information of traders about future states of the world, is much closer than to the early experiments. In general, subsequent work is explicitly built upon more recent "perfect foresight" or "rational expectations" theory, rather than on textbook microeconomics. Note that, in our terms, experimental economics thus develops to testing further aspects of the «Hayek hypothesis», as distinct from the first competitive equilibrium, or "information revelation", element of which Smith [1982] states something like a standard version which, if ever, is referred to as "the" Hayek hypothesis in later contributions.

Forsythe, Palfrey and Plott [1982], Asset Valuation in an Experimental Market

Aggregation of information [HH 1, 2]
laboratory test by oral double auction markets for multi–period assets
#: 8–9

The present paper can be looked upon as a *pilot study* to the whole lot of subsequent tests building on "rational expectations" theory. The authors establish a setting with two or three types of "investors" who differ with respect to their dividend schedules for an asset with *two–period life* and, hence, have different preferences. Individual payoffs in either of the two periods are strictly private knowledge. In spite of designating subjects as purely buyers or sellers, all of them are allowed to buy and sell their initial endowment of two or three certificates, and to resale those that they purchased before on the two periods' spot markets. In one out of five experiments, the period 2 spot market is replaced by a *futures market* which is run simultaneously with the period 1 spot market.

There are two additional alterations of standard experimental design: First, there is an artificial experimental currency which is only later converted in dollars, in order to "finance" initial endowments that are not converted into reward

payments. Secondly, there are no commissions paid, since individuals can be on either side of the market, thus leading to an infinite number of possible transactions. When assessing the results, the occurrence of transaction costs is taken into account, though.
The experimental results are interpreted in the light of a set of hypotheses which first are stated formally. Basically, they encompass two alternative presumptions, namely that traders either act according to "naïve expectations", simply relying on their private information on own payoffs, or exhibit "perfect foresight", i. e. buy or sell at the two periods' maximum valuation of the traded asset.

Results: Generally, experimental data show strong support for the perfect foresight hypothesis, with prices converging to the predicted equilibrium level in second periods' markets and, less rapidly, in first periods' markets. Throughout, price convergence is from below, indicating that trade *starts* from somewhat close to naïve expectations level, as was presumed by the authors. The fact that prices seem to adjust slightly below perfect foresight predictions could be explained by imputing minimal costs of trading.
Efficiency, as measured by the after trade allocation of certificates, is very high, since after one or two replications almost no unit of asset is held by the "wrong" type of traders. Such quantity convergence is much faster with the futures market, whereas experiencedness of traders seems to have no similar impact. The alternative measure of efficiency, i. e. actual payoffs as percentage of maximum possible payoffs, confirms the above observations.

Plott and Sunder [1982], Efficiency of Experimental Security Markets with Insider Information: An Application of Rational–Expectations Models

Aggregation of (asymmetric) information under uncertainty
[HH 2, 1]

Laboratory test by oral double auction security markets

#: 9–12

The reported tests mark a significantly new step in the evolution of experimental economics. The authors move to examining information aggregation in laboratory security markets with uncertain, i. e. state contingent, payoffs. Explicitly receiving newly emerged *rational expectations theory* to experimental economics, they substantially deviate from traditional commodity market design, although the authors attempt to create laboratory markets which are sufficiently simple. E. g. they abstract from the time dimension of actual security markets (or rather leave it to Forsythe, Palfrey and Plott [1982]), focusing solely on the second important dimension of such markets, namely *uncertainty*.
Therefore, the authors establish a market with one security, two possible states

of the world, and three groups of trader "types", each with differing valuations on the securities per state. Hence, relevant information is not only strictly private knowledge about individual valuations of the certificates but, moreover, information about the underlying state of nature which is randomly chosen. After some first trading rounds serving as training periods, such information is given to some *insider agents* whose number and identity rest unknown to other participants. One out of five markets is run with less than complete information for the insiders, whereas in all other markets some traders are fully informed about the respective state of the world. In the last market, the authors increase the number of the relevant states from two to three.

The results are assessed in the light of two alternative models according to which some hypotheses concerning price behaviour, profits and market efficiency are stated formally. Basically, following the predictions of fully revealing "rational expectations" (R. E.) theory, prices in equilibrium ought to reveal the true state of nature because participants endogenously condition their expectations on the price formation process. If they do not, "prior information" (P. I.) equilibrium should prevail in which prices rather correspond to the exogenous expected value of the traded securities.

Results: Data from the first market in which even insiders were only partially informed show little support for the R. E. model. Throughout the other markets, however, prices strongly converge to the R. E. equilibrium level of each period. Whenever R. E. price predictions and P. I. equilibrium differ, the R. E. model clearly outperforms the latter. It is worth mentioning that this is to the authors' surprise because they initially favoured P. I. hypotheses, as to forecasting the traders' behaviour. Even in market 5, with a three–state environment, the R. E. model applies as readily as before: The market not only reveals that some state has *not* occurred but rather transmits full information on exactly what state has been chosen.

Forecasts of the R. E. model are also superior to its alternative as far as after trade allocation of the securities and the distribution of profits are concerned. In particular, profits of insiders and of the uninformed agents tend to be equalized as information spreads and experience in the market cumulates, thus indicating that the initial advantage of insiders vanishes with replication. Market efficiency, as measured by an application of the standard formula adapted to the case of uncertainty, is very close to 100 per cent, i. e. to the R. E. prediction.

Finally, the authors attempt to give some more clues about possible sources of information which might explain why their markets tend to be more accurate in aggregating and disseminating information during later periods of trade. Besides occasional curses, laughter, or other signs of emotion which are more or less unavoidable in oral auctions, they consider another source of information, as distinct from the pure sequence of previous price quotes: The market activity of

insiders in early stages of the market indicates that competition among insiders, evidenced (a) by their opening bids and asks or (b) by certain "critical" offers which substantially alter the current quotation above or below some "safe" level at which uninformed agents opened the market, reveals the actual state to the uninformed. The more they get used to looking, or waiting, for such information, the better the market works.

Smith and Williams [1983], An Experimental Comparison of Alternative Rules for Competitive Market Exchange

Revelation of information [HH 1] laboratory test by computerized double auction commodity markets #: 8

The experimental design, although appearing to be somewhat outdated at first sight, represents a remarkable improvement, as compared to the computerized double auction experiments reported by Smith [1982] and Williams [1980].

The authors' main task is to compare *alternative rules* governing price quotes when previous offers are still standing. Therefore, they complete the above set of rules (a) to (c) (cf. Williams [1980]) with another queuing rule which they call the "rank queue" institution: Price quotes ought to progress so as to reduce the bid–ask spread, but any subsequent offer which is less favourable than the currently standing best one, rather than being rejected, is placed in a queue according to its rank in the price scale, i. e. from highest to lowest bid or from lowest to highest ask, respectively. Additionally, queued offers may be withdrawn or replaced by the maker at any time.

<u>*Results*</u>: The authors conduct a total of 21 experiments under the four alternative rules on price quotations, with both experienced and inexperienced participants. Throughout, supply and demand schedules are basically identical. The 1980 result that experience matters a lot with computerized trade is strongly confirmed. What is more, the old time queue rule can clearly be shown as destabilizing contract prices, whereas the rank queue institution turns out to be a powerful means to ensure fast and strong convergence to competitive price equilibrium and to achieve high efficiency outcomes.

Forsythe, Palfrey and Plott [1984], Futures Markets and Informational Efficiency: A Laboratory Examination

Aggregation of information [HH 1, 2]

Laboratory test by oral double auction markets for multi–period assets

#: 8

The present paper builds much on the previous article by the same authors [1982], but it focuses on the comparison of experiments with additional *futures markets* for assets with two–period lives to those with *distinct spot markets* in each period only. Again, there are several trader types with different preferences, induced by different dividend schedules for either period. Hypotheses according to either "naïve" ("maximin") or "rational" (perfect foresight) expectations (R. E.) are stated like in the 1982 article. Unlike as in any other experiment published so far, the authors use a rather complicated return function which is essentially non-linear in assets held. Since trades can only occur in integrate discrete units of the asset, there are a range of prices which support either model.

Results: Generally, the naïve expectations hypotheses can be rejected for all experiments in both periods during later repetitions. They may, to some extent, apply to early stages of each market, such that participants can be regarded as starting at, or close to, naïve equilibrium prices prior to acquiring information about other participants' preferences and gaining some experience with their environment.

The hypothesis that in experiments with futures markets, spot markets converge more rapidly to an R. E. equilibrium than with sequential markets only is strongly supported. It is interesting to note, however, that in early stages of the experiments, spot prices exhibit a considerably higher variability with a futures market than without them. According to the authors, though, this is what is to be expected if futures markets publicize existing private information, thus leading spot prices simply to adjust more quickly (see, however, Friedman, Harrison and Salmon [1984] for evidence to the contrary).

Final conclusions on after trade allocations of assets and on market efficiency confirm the above main results that (a) the R. E. model predicts, with great accuracy, market outcomes in the reported experiments, and that (b) the introduction of futures markets facilitates and speeds up convergence to R. E. equilibrium.

Friedman, Harrison and Salmon [1984], The Informational Efficiency of Experimental Asset Markets

Aggregation of information under uncertainty
[HH 2, 1]

Laboratory test by oral double auction security markets

#: 9

The authors report on a series of experiments which were partially run before those described in Forsythe, Palfrey and Plott [1984]. They also focus on the role of *futures markets* in price dynamics and allocations of multi–period assets. However, they combine such testing of the time dimension of real world security markets with some additional elements of *uncertainty*, as were present in the Plott and Sunder [1982] experiments.

Inasmuch as traders with strictly private knowledge of own dividend schedules, or preferences, do not know at first what prices will be available to them, there is an endogenous type of uncertainty in every market. The authors refer to such uncertainty which occurred in all previous experimental work but is greatly enhanced in multi–period asset trade as "*market uncertainty*". Therefore, they run a first series of experiments in order to test if this type of uncertainty can be overcome in a world with one three–period lived asset, with three types of agents which differ with respect to their dividend profile over time, and with either three distinct period spot markets or a futures market for last periods' asset holdings.

If, additionally, dividends of the traded asset are state contingent, another type of (exogenous) uncertainty occurs which the authors call "*event uncertainty*". Moreover, if under such circumstances some traders are informed about the actual state of nature, whereas others are not, there is what the author refer to as "*insider uncertainty*". Consequently, they set up two further series of experiments, each consisting of a world with or without futures markets, respectively. Both these series are in most respects identical to the first series' setting. In series 2, however, there are two possible states on which dividends depend, in addition to their differing across trader types and periods. In each replication, though, event uncertainty is resolved after the first period of trade. This design resembles the first no–information periods of Plott and Sunder's [1982] tests but the *combination* of event uncertainty, multi–period assets and a futures market actually represents a new step in experimental work.

Things are no different with the series 3 markets where one member of each group of agents is privately informed about which state will occur before the first period of trade takes place. Existence of insiders is common knowledge but non–insiders have no prior knowledge about the identity of insiders. Again, the distinct features of asymmetrically informed traders, multi–period trade and futures markets have never been simultaneously tested before.

As a tool for assessing their results, the authors compute a set of price and allocation predictions for each of their markets, based (a) on prior information vs. rational expectations (R. E.) models and, as a further distinction with respect

to the latter, (b) on either strong form efficiency ("perfect foresight") or semi–strong form efficiency ("uninformed rational expectations") concepts.

Results: Two predictions of the authors which come from theory were generally supported by previous experimental work, namely that market outcome converges to stronger–form informational efficiency, and that the presence of a futures market speeds such convergence. Broadly speaking, these predictions are confirmed by the reported experiments with two exceptions: For each first period in the second series, there was no information at all available about the underlying state of nature. Bearing this in mind, it is not surprising to see the respective prices converging to the "uninformed" R. E. level only, thus indicating that traders condition their beliefs on market prices which then reflect all private, but not complete, information. Such price behaviour, of course, cannot be overcome by the introduction of a futures market. Secondly, in the final series, first periods' prices as well remain at this semi–strong form efficiency level for most of the replications as long as there is no futures market. However, inside information is leaked out rather quickly, as indicated by convergence of spot prices to perfect foresight equilibrium levels, if a futures market is established.
After trade allocations of certificates correspond to the above statements, and a more rigorous statistical analysis of the results yields no further insight. The findings on the informational role of futures markets, however, deserve some more interest. Unlike Forsythe, Palfrey and Plott [1984], the authors observe that presence of a futures market not only enhances efficiency but stabilizes spot markets or reduces spot price volatility. The theoretical justification is clear, although there is a strong controversy in both politics and economics about it: When futures markets are open, markets are more nearly complete and more information is available. Hence, the authors attribute the opposite findings of Forsythe et al. to their traders' inexperiencedness which was not isolated there as a single treatment variable.

Banks [1985], Price–conveyed Information versus Observed Insider Behavior: A Note

Aggregation of (asymmetric) information under uncertainty
[HH 2, 1]

Laboratory test by oral double auction security markets

#: 12

In his comment, the author points to a source of possible misinterpretation in both previous tests on information aggregation under uncertainty. In Plott and Sunder's [1982], as well as in most of Friedman, Harrison and Salmon's [1984] markets, the *information structure* is fixed in that the *same* traders are informed in almost every period.

Hence, the strong support for the rational expectations (R. E.) model in either experiments could as well be due to the ability of initially uninformed participants to guess the identity of informed traders and then to simply use this knowledge about the insiders' identities, as opposed to gain price–conveyed information from the market.

Attempting to overcome this problem, the author conducts a replication of one of the Plott and Sunder experiments (with one security, three possible states of the world, and three types of traders). The major alteration is with the information structure, such that informed traders are chosen at random for each period of trade, and the combination of the informed mostly differs from one period to another. A minor alteration concerns the auctioning institutions where an "improvement" rule for subsequent offers, as compared to the outstanding best offer, is established.

Results: The results of the new experiment basically confirm the observations of both Plott and Sunder and Friedman et al. regarding price dynamics and efficiency of the markets. Again, R. E. predictions clearly outperform prior information forecasts whenever they differ. However, the conclusions drawn from the ratio of informed traders' profits to the uninformed traders' profits, namely that the ratio declines to values near 100 per cent as the uninformed become able to learn the state from market prices, is weakened. Variability of the ratio has lessened a lot by constantly altering the information structure, and final periods' values remain above those of the previous tests. Although the markets become in some sense more revealing over time, the fixed information structure may have overstated such revelation, especially in Plott and Sunder's setup.

Copeland and Friedman [1987], The Effect of Sequential Information Arrival on Asset Prices: An Experimental Study

Aggregation of (asymmetric) information under uncertainty
[HH 2, 1]

laboratory test by computerized double auction security markets

#: 9

The present paper represents the first report on *computerized* double auction trade in a more complex environment, with (three types of) traders having different preferences and with *uncertainty* about the actual state of nature (one out of two). Besides the task of replicating earlier results under the conditions of automated trade, the authors focus on two treatment variables: In each of their experiments and for all participants, event uncertainty is resolved during each trading period. However, information arrives either *simultaneously* at all participants, or *sequentially* at one group of trader type after another. Secondly, the *content of information* is either homogeneous in that all participants receive "good news" (state 1) or "bad news" (state 2), or heterogeneous in that it differs across trader types.
Additionally, the authors attempt to observe the influence of what they call "nuisance variables": All participants of the computerized trade are trained in some initial pilot experiments. Nevertheless, the process of learning during each experiment has to be taken into account, at least as far as some distinct features of its stationary repetition are concerned. Additionally, the authors consider an alternative payoff procedure in which a subject would no longer earn substantial profits even if he refused to transact, but receives only "trading profits" instead (Note that, in a sense, this means reintroducing commissions).
The authors use three competing concepts to predict price behaviour and allocations in order to assess their data: the fully revealing ("telepathic") rational expectations (TRE) hypothesis which corresponds to strong form efficiency of the market, the ordinary rational expectations (ORE) model as a weaker, or semi–strong form, variant of the former, and the (prior) private information (PI) equilibrium in which traders would not condition their beliefs on the market's process at all.

<u>*Results*</u>: Analysis of experimental evidence clearly supports that rational expectations predictions outperform private information forecasts, as regards price convergence and allocation of certificates. Furthermore, the TRE model turns out to be superior to ORE predictions as far as price behaviour is concerned, allocation forecasts being no different. In accordance with the authors' presumptions, the "nuisance" variables have no observable impact on these results. Hence, they conclude that neither learning nor the payoff method matter with experienced subjects.
Results regarding the treatment variables on which the experiments focus contradict the authors' predictions to some extent, though. In advance, they suggested that rational expectations predictions would do significantly better in

simpler environments, i. e. with simultaneous or homogeneous information, than in the informationally more heterogeneous settings. However, their tests detect only insignificantly "better" price and allocation convergence in the former cases. To their surprise, they find trading volume substantially higher in environments with simultaneous information arrival which contradicts all theoretical concepts they build on. To their thinking, this indicates the need for further development of concepts such as "Bayesian" and "dynamic" rational expectations as a foundation for new experiments.

Plott and Sunder [1988], Rational Expectations and the Aggregation of Diverse Information in Laboratory Security Markets

Aggregation of (diverse, but collectively complete) information under uncertainty
[HH 2, 1]

laboratory test by oral double auction security markets

#: 8–12

The authors discuss three series (A–C) of experimental markets all of which should have performed identically according to rational expectations (R. E.) theory: Basically (in series A), single securities with one period lives and state contingent dividends are traded between individuals with different preferences and varying expectations about the underlying state of nature. Different expectations are induced by partially revealing the actual state to traders, such that participants privately hold *diverse information* (one out of three states is *not* occurring), whereas the market as a whole is completely informed.

In series B, the single security is replaced by a *complete set of state contingent claims*, whereas in series C, traders' preferences are equalized by paying *identical* (i. e. only state contingent) *dividends* for a single compound security, again.

The results are examined in the light of three competing models of security behaviour: The (fully revealing) R. E. equilibrium vs. the "prior information" equilibrium and the "maximin" model which are used as benchmarks against which to evaluate R. E., or "as starting points in dynamic models of formation of rational expectations"—a subject the authors finally have not a conclusion, but only a mere conjecture about when assessing their data.

<u>*Results*</u>: For reasons that remain ultimately undiscovered, the series A markets generally fail to meet R. E. price predictions. Furthermore, they lack efficiency as measured by effective vs. possible gains from trade and, hence, they do not successfully aggregate the diverse information. R. E. predictions about the after trade allocation of certificates and about profit distribution seem to hold, though.

As far as the series B and C markets are concerned, the R. E. model clearly outperforms the alternatives in all regards. These results with a complete set of "Arrow–Debreu securities" being not so much of a surprise, the authors discuss the role of identical preferences or, more generally, of some knowledge about other participants' preferences for the process of information aggregation and the operation of R. E. principles.

Smith, Suchanek and Williams [1988], Bubbles, Crashes, and Endogenous Expectations in Experimental Spot Asset Markets

Aggregation of information under uncertainty [HH 1, 2] laboratory test by computerized double auction security markets #: 9–12

More than in all previous work, the authors are interested in the *process of price adjustment* itself. Their experimental design has some characteristics by which it focuses solely on the adjustment of the participants' expectations about the uncertain state of the world: In each market, there are three "classes" of traders who differ with respect to their initial endowment but not with respect to their preferences. Traders are allowed to trade in units of a single asset with one–period life which is to yield dividends contingent on one out of four possible states of the world. There is *no prior information* to anyone on which state will actually occur, though.
Hence, the first objective in testing rational expectations theory is to determine whether in such environment, agents would engage in trading, at all. The second objective, given that trading occurs, is to characterize the observed price adjustment paths.
The authors run a total of twenty–two markets (without intervention, or disruption, by the experimenters), most of which with these identical features, involving both inexperienced and experienced subjects. Some of the experiments encompass *forecasting* of next period's mean asset price, with forecasts remaining private knowledge.

<u>*Results*</u>: The first result is that inducing different private dividend values on traders is obviously not a necessary condition for the observance of trade activities. Even if it is common knowledge that identical probabilistic dividends are to be paid on asset holdings at the end of each period, exchange, sometimes in large volume, occurs. Nonetheless, all experiments with experienced traders, and most of those with inexperienced traders converge to "near" (uninformed) rational expectations predictions prior to the last trading period. Expectations seem to be adaptive, and adaptation over time is to rational expectation equilibrium outcomes when "fundamentals" remain unchanged.

However, only four of the reported markets, all using experienced subjects, provide strong support for the rational expectations model in that prices constantly correspond to sustainable expectations on asset returns. In 14 cases of which 9 involved experienced subjects the market was characterized by price bubbles followed by crashes relative to intrinsic dividend values. This occurred even if experienced participants did not expect the possibility of a bubble from earlier participation.

Statistical analysis supports the hypothesis that such price behaviour is due to excess demand arising from homegrown capital gains expectations after an initial period of price depression (probably caused by risk aversion) which turn out to be unsustainable over time. The collapse tends to follow a thinning of demand, and is characterized by a trading volume which is smaller than the volume during the bubble phase.

The forecasting experiments generally show a tendency to over–predict mean prices and turn out to fail to predict abrupt increases, or decreases, in price and both upper and lower turning points of prices. Moreover, forecasts seem to be highly adaptive, with changes from one period to another being significantly related to forecast errors in previous periods. However, there are some agents who exhibit a high degree of forecasting accuracy and, hence, tend to earn more money. With experience, though, participants tend to converge to common (and sustainable) dividend value expectations as behavioural uncertainty decreases.

In a later contribution, King et al. [1993] report on a similar series of experiments involving short sales, margin purchases (i. e. with borrowed funds), a brokerage fee and some further alterations. In spite of their assumption that by any of these means bubbles should be significantly shortened and dampened, they find asset prices robustly deviating from intrinsic values—at least as long as subjects are not experienced by participating in the experimental markets once ore even twice.

Forsythe and Lundholm [1990], Information Aggregation in an Experimental Market

Aggregation of (diverse, but collectively complete) information under uncertainty
[HH 2, 1]
laboratory test by oral double auction security markets

#: 12

Building on Plott and Sunder [1988], the authors try to identify conditions under which the "rational expectations" (R. E.) model successfully predicts equilibrium behaviour of markets with a single state contingent security, different preferences of traders, and *diverse*, but collectively complete, *information*.
In order to give R. E. predictions a better chance, they alter the experimental design significantly: Besides increasing the number of traders in each market, they make all market parameters—including the differing dividend schedules—*common knowledge* and require all traders to participate in markets on two consecutive nights, thus securing that participants be *experienced* during the second–night sessions, at least.
In a first series of markets, the authors additionally rotate payoff schedules between trader types so that each became familiar with all such schedules in use. This feature is dropped in a second series while, in a third series, even the common knowledge property of individual dividends is omitted. In a final series, common knowledge is re–established but each traders' payoff schedule is randomly determined from one period to the next. Again, the results are interpreted in the light of three alternative models for explaining the traders' market behaviour: R. E. vs. "prior information" and "maximin" hypotheses.

<u>*Results*</u>: Given the alterations of market design as represented by the first series, the authors conclude that an R. E. equilibrium can be obtained on single compound securities markets, with traders holding diverse information and different preferences. Evidence from the second–night markets shows that the R. E. model clearly outperforms either exogenous information model in predicting both prices and after trade allocations. The corresponding first–night results indicate, though, that some degree of experience is necessary, in addition to the common knowledge of dividends or, more generally, of the set of other traders' preferences.
The counter–experiments in the third series show that experience alone, without common knowledge, is also not sufficient to achieve R. E. equilibrium. With experienced traders and common knowledge however, it is not necessary that traders actually use other traders' payoff schedules, nor that they know each individual trader's payoffs. Furthermore, the experience required must not necessarily be drawn from the same parameter set or from identical market design.

Copeland and Friedman [1991], Partial Revelation of Information in Experimental Asset Markets

Acquisition and aggregation of information under uncertainty
[HH 3, 2, 1]

Laboratory test by computerized double auction security markets

#: 9

Apart from using a *computerized* double auction market design, the authors conduct an experiment which is rather similar to their own [1987] work, i. e. there is no common knowledge about the (different) state contingent payoff schedules of other traders. Information on the underlying state of the world is given either sequentially or simultaneously to the different types of traders, as distinguished by different dividend schedules. Furthermore, the authors distinguish between two kinds of markets where the state of nature is either homogeneous or heterogeneous for all types of traders.
The main difference is that in about half of their markets, there is a non–computerized (sealed bid) *auction for advance information* on the respective state of nature and on own payoffs, that is, before security trade opens: At uniform prices (equal to the fourth highest bid) the three highest bidders anonymously receive a corresponding message, whereas other traders are only informed about the price of such information.
The main task of the paper is to compare a newly proposed "partially revealed expectations" (PRE) model to the more current models of "fully revealed" (FRE) or "non revealed" (NRE) private information, as regards the prediction of price behaviour and allocations on the experimental markets.
In a further article, Copeland and Friedman [1992] concentrate exclusively on the eight markets involving endogenous decisions on information acquisition. There, they apply another analytical tool, namely some basic concepts of recent *game theory* , to the same data.

<u>*Results*</u>: With regard to forecasting securities prices, the FRE hypothesis significantly outperforms the alternatives, whereas it fails when other features, namely the allocation of securities and, above all, the price and allocation of purchased information, are focused.
According to the FRE model, the price of information should have been zero in any case. The PRE model predicts zero information prices for the "homogeneous" markets, as well, since all information can be unambiguously inferred from the security's prices when some traders become informed. For informationally "heterogeneous" environments however, it predicts positive information values throughout any trading period because the correspondence between observable trading behaviour and the actual state of nature is not precise. These forecasts are best met by the experimental results, with

information prices generally tending to fall from one trading period to another, but converging to zero only on markets with homogeneous payoff states.
In their 1992 article, the authors point out that in the FRE case, in the NRE case, and in the simple (prior) "private information" case, the predicted values of the price of information each correspond to Nash equilibria in an "information purchase game", whereas the PRE model, as they see it, has no specific content in this framework. Hence, it is now the NRE model which is comparatively more accurate in forecasting prices and allocations of purchased information in more complex environments. Apart from that, the interpretation is not significantly altered.

Davis and Williams [1991], The Hayek Hypothesis in Experimental Auctions

Revelation of information
[HH 1]

Laboratory test by computerized double auction and posted offer commodity markets

#: 5–10

Building on previous work by Holt, Langan and Villamil [1986], the authors return to an informationally rather non–complex problem, focusing on the occurrence of s*trategic behaviour* in simple goods trade when all information about supply and demand schedules is strictly private. Therefore, they set up an environment with "seller market power", i. e. with the possibility to increase the market price unilaterally through strategic withholding of supply. The experiments are conducted with both inexperienced and experienced participants.
The main interest of the authors lies with comparing strategic behaviour, market prices and extracted gains from trade under *alternative trading institutions*: Thus, they repeat their experiment (a) on computerized double auction markets, (b) on computerized posted offer markets, and (c) like (b) but with buyer behaviour simulated by the computer.

Results: The results of the reported experiments are not quite clear cut: On either market, the authors observe some deviation from competitive equilibrium prices in the direction which ought to be expected when sellers successfully exercise some market power. Under the posted offer institution which is less favourable for buyers who have only the option of purchasing or not purchasing, mean prices tend to be higher than under double auction rules. Efficiency, as measured by gains from trade, is generally high, though, but on the posted offer markets, it obviously takes more time, or trading periods, to achieve levels above 90 %.
The most puzzling feature of the results is that, independent of the respective market institutions, there is little evidence for strategic supply withholding. All the same, since there are alternative ways to exercise seller market power, the authors are unable to determine to what extent the supposed relation to market prices above the competitive equilibrium level holds.

O'Brien and Srivastava [1991], Dynamic Stock Markets with Multiple Assets: An Experimental Analysis

Aggregation of (diverse) information under uncertainty
[HH 2, 1]

laboratory test in computerized double auction security markets

#: 12–16

With the intention "to make information aggregation difficult", the authors choose a rather sophisticated experimental design which incorporates *multiple assets* with two–period lives and several arbitrage relationships. Payoffs are state contingent but uniform across traders, according to a payoff schedule which is common knowledge, whereas the (uniform) rate by which experimental cash will later be converted into dollars is privately told to each trader. Thus, each trader knows but his own preferences. Information about the underlying state of nature is announced to randomly chosen subsets of traders, so that traders privately hold *diverse information*, and the market as a whole can be either completely or partially informed.
The trading rules in the reported experiment deserve some further interest: The authors combine "rank queuing" with a strictly binding improvement rule governing all price quotations, such that any subsequent bid (ask) must be at least as high as (no lower than) the outstanding highest bid (lowest ask). Once a market clears at the currently highest bid (lowest ask), the bid (ask) queue is flushed completely. Either rule precludes a lot of potentially relevant information from being transmitted to other traders.
Finally, the authors establish a complicated mechanism in order to ensure *risk neutrality* by which cash prizes are completely equalized among traders, and the risk of losses—as usual in laboratory markets—is removed, thus weakening a trader's incentive to use market information carefully.

<u>*Results*</u>: Unlike as in most of previous experimental work, the results indicate that even after several replications, there is no convergence to "fully" or "partially" revealing rational expectations (R. E.) prices, at least as far as "first" periods of trading—with a more complex environment in that there are two periods' state contingent dividends to be computed—are concerned. Since this is independent of the question whether markets as a whole are completely informed or not, the authors conclude that information aggregation, as predicted by R. E. models, does not perform very well in comparatively more complex settings. Especially for first periods, the alternative "prior information" hypothesis works much better when compared with actual market prices.
With all arbitrage relationships holding and standard tests being unable to detect the source of informational inefficiency, the authors ultimately lack any explanation for such failure. In some sense, they may be trapped in with the

complex, but rather artificial, experimental design and with the incentive system they installed on their own account.

DeJong, Forsythe, Lundholm and Watts [1992], Do Prices Convey Information?

Aggregation of (asymmetric) information under uncertainty
[HH 2, 1]

laboratory test by computerized double auction security markets

#: 12

Stated briefly, the present paper reports on a *computerized* replication of two of the Plott and Sunder [1982] experiments, i. e. tests on rational expectations behaviour of traders who differ with respect to their preferences when they are they facing uncertainty about the actual state of nature, or are asymmetrically informed about it, respectively. Besides comparing results form oral to computerized auctions, the authors' experimental design does not go much beyond Copeland and Friedman's [1987], though.

Their main task is to examine to what extent the outcome of earlier experiments of that kind was dependent on the richer set of information which is unavoidably transmitted in oral double auction, as compared to automatic trading institutions where *price information alone* is available. Thus, computerized trade provides a more rigorous test on rational expectations (R. E.) models according to which traders condition their beliefs on market prices only.

<u>*Results*</u>: The comparison of both oral and computerized double auctions generally supports the R. E. hypothesis, as well as confirming earlier results on characteristics of automatic trade: In the latter, market prices and allocations clearly converge towards rational expectations equilibrium levels but the process of convergence tends to be much slower, although there is substantially more trading per period (see Williams [1980]). Nevertheless, these differences which can be observed while information spreads and prices are adjusting have no effect on *final* allocations and on profits of informed traders.

Sunder [1992], Market for Information: Experimental Evidence

Acquisition and aggregation of information under uncertainty *[HH 3, 2, 1]*
laboratory test by oral and computerized double auction security markets
#: 8–12

Building much on the previous work by Plott and Sunder [1982, 1988], the author moves to examining markets where recipients of information are no longer determined exogenously, and information is no longer costless. Thus—with some similarities to Copeland and Friedman's [1991] experiments—, he completes the 1988 design of a security market with an additional *market for information* about the underlying state of nature. He reports on two series of experiments (A, B) in which either the price of information or the number of traders who are allowed to buy information are fixed.

In the series A (fixed number) markets, traders are invited to submit *sealed bids* for the purchase of information. The four highest bidders receive information at the fifth highest price which is then made common knowledge.

In the *fixed price* markets (series B), the price of information is publicly announced at the beginning of each trading period. The number of traders who actually bought information is communicated in most of these markets, but in some of them it is not. For obvious reasons, the identity of buyers is never revealed.

As a benchmark for assessing the results, the author uses a "fully revealing" expectations (FRE) model which implies that information, although it is socially valued, has no private value. If any one trader buys information, it will be revealed to all market participants and everyone will benefit equally from it. Hence, there is no (persisting) incentive to purchase information at any price.

Alternatively, he considers a "noisy" rational expectations model in which prices do not fully reveal the purchased information, thus allowing informed traders to recover their costs of information acquisition. It is worth mentioning that in double auction markets, there is room for such cost recovery, even if market prices ultimately reveal all information to the uninformed, because there is no unique asset price during each trading period.

<u>*Results*</u>: Evidence from the reported experiments shows that in the series A markets, with the supply of information held constant, the behaviour of both asset and information markets converges towards the predictions of the FRE model: The price of information drops close to zero, as the asset market—in terms of asset prices, after trade allocations and market efficiency—converges to the FRE equilibrium. The distribution of net (of cost of information) profits across traders tends to be equal.

In the series B markets with fixed prices of information, however, the behaviour of asset prices corresponds rather to predictions of the "noisy" rational expectations model: Informativeness and efficiency are lower, i. e. the convergence of market prices to FRE levels is erratic, and the number of buyers of information fluctuates but shows no tendency towards zero. Gross profits of the informed traders are generally higher but their net profits are statistically indistinguishable from the profits of the uninformed.

The fact that, for some periods, in series B markets convergence to a "wrong" price occurs, i. e. to a price that corresponds to a wrong state of nature, is particularly interesting: In most of these cases, all informed traders after selling their initial endowment become inactive, and the uninformed who are trying an information free ride—or, "the blind leading the blind"—arrive at a wrong conclusion.

References

BANKS, Jeffrey S. [1985], Price–conveyed Information versus Observed Insider Behavior: A Note on Rational Expectations Convergence, *Journal of Political Economy* 93, 807–815

CLARKE, John M. [1940], Toward a Theory of Workable Competition, *American Economic Review* 30, 241–256

COPELAND, Thomas E. and Daniel FRIEDMAN [1987], The Effect of Sequential Information Arrival on Asset Prices, *The Journal of Finance* 42, 763–797

—— [1991], Partial Revelation of Information in Experimental Asset Markets, *The Journal of Finance* 46, 265–295

—— [1992], The Market Value of Information: Some Experimental Results, *Journal of Business* 65, 241–266

DAVIS, Douglas D. and Arlington W. WILLIAMS [1991], The Hayek Hypothesis in Experimental Auctions, *Economic Inquiry* 29, 261–274

DAY, Richard A. and Ping CHEN [1993, eds.], Nonlinear Dynamics and Evolutionary Economics (Oxford: Oxford University Press)

DE JONG, Douglas V., Robert FORSYTHE, Russell LUNDHOLM and Susan WATTS [1992], Do Prices Convey Information? Further Empirical Evidence, *Research in experimental economics* 5, 61–80

FORSYTHE, Robert and Russell LUNDHOLM [1990], Information Aggregation in an Experimental Market, *Econometrica* 58, 309–347

FORSYTHE, Robert, Forrest NELSON, George NEUMANN and Jack WRIGHT [1991], The Iowa Presidential Stock Market: A Field Experiment, *Research in experimental economics* 4, 1–43

—— [1992], Anatomy of an Experimental Political Stock Market, *American Economic Review* 82, 1142–1161

FORSYTHE, Robert, Thomas R. PALFREY and Charles R. PLOTT [1982], Asset Valuation in an Experimental Market, *Econometrica* 50, 537–567

—— [1984], Futures Markets and Informational Efficiency: A Laboratory Examination, *The Journal of Finance* 39, 955–981

FRIEDMAN, Daniel, Glenn W. HARRISON and Jon W. SALMON [1984], The Informational Efficiency of Experimental Asset Markets, *Journal of Political Economy* 92, 349–408

FUDENBERG, Drew and Jean TIROLE [1991], Game Theory (Cambridge MA: MIT Press)

GROSSMAN, Sandford J. [1977], The Existence of Futures Markets, Noisy Rational Expectations and Informational Externalities, *Review of Economic Studies* 44, 431–449

—— [1981], An Introduction to the Theory of Rational Expectations under Asymmetric Information, *Review of Economic Studies* 48, 541–559

GROSSMAN, Sandford J. and Joseph E. STIGLITZ [1980], On the Impossibility of Informationally Efficient Markets, *American Economic Review* 70, 393–408

HAYEK, Friedrich A. von [1945], The Use of Knowledge in Society (first published in: *American Economic Review* 35, 519–530), reprinted in: Nishiyama and Leube [1984], 211–224

—— [1946], Der Sinn des Wettbewerbs, reprinted in: Hayek [1976], 122–140

—— [1968], Competition as a Discovery Procedure, reprinted in: Nishiyama and Leube [1984], 254–265

—— [1976], Individualismus und wirtschaftliche Ordnung, Second edition (Salzburg: Neugebauer)

HOLT, Charles A., Loren W. LANGAN and Anne P. VILLAMIL [1986], Market Power in Oral Double Auctions, *Economic Inquiry* 24, 107–123

HURWICZ, Leonid [1972], On Informationally Decentralized Systems, in: MacGuire and Radner [1972], 297–336

KANTZENBACH, Erhard [1967], Die Funktionsfähigkeit des Wettbewerbs, Second edition (Göttingen: Vandenhoeck & Ruprecht)

KING, Ronald R., Vernon L. SMITH, Arlington W. WILLIAMS and Mark van BOENING, The Robustness of Bubbles and Crashes in Experimental Stock Markets, in: Day and Chen [1993], 183–200

KNIGHT, Bruce [1976], The Ballad of "Right Price", reprinted in: Trebeis [1979], 149–153
KREPS, David M. [1990], A Course in Microeconomic Theory (New York: Harvester Wheatsheaf)

LUCAS, Robert E. [1972], Expectations and the Neutrality of Money, J*ournal of Economic Theory* 4, 103–124

MADHAVAN, Ananth [1992], Trading Mechanisms in Securities Markets, *The Journal of Finance* 47, 607–641

MACGUIRE, C. B. and Roy RADNER [1972, eds.], Decision and organization (London: North Holland)

MILLER, Ross M., Charles R. PLOTT and Vernon L. SMITH [1977], Intertemporal Competitive Equilibrium: An Experimental Study of Speculation, *Quarterly Journal of Economics* 91, 599–624 (reprinted in: Smith [1991], 128–153)

MÜCKL, Wolfgang J. [1988], Innovation und Wettbewerb. Zur dynamischen Ineffizienz des Marktes, *Der Bürger im Staat* 38, 178–183

NELSON, Richard R. and Sidney G. WINTER [1982], The Schumpeterian Tradeoff Revisited, *American Economic Review* 72, 114–132

NISHIYAMA, Chiaki and Kurt R. LEUBE [1984], The Essence of Hayek (Stanford CA: Hoover Institution Press)

O'BRIEN, John and Sanjay SRIVASTAVA [1991], Dynamic Stock Markets with Multiple Assets: An Experimental Analysis, *The Journal of Finance* 46, 1811–1838

PLOTT, Charles R. [1979], The Application of Laboratory Experimental Methods to Public Choice, in: Russell [1979], 137–157

PLOTT, Charles R. and Vernon L. SMITH [1978], An Experimental Examination of two Exchange Institutions, *Review of Economic Studies* 45, 133–153 (reprinted in: Smith [1989], 133–153)

PLOTT, Charles R. and Shyam SUNDER [1982], Efficiency of Experimental Security Markets with Insider Information, *Journal of Political Economy* 90, 663–698

—— [1988], Rational Expectations and the Aggregation of Diverse Information in Laboratory Security Markets, *Econometrica* 56, 1085–1118

Research in Experimental Economics, 5 vol. [1979–92], ed. by Vernon L. Smith (vol. 1–3) and R. Mark Isaac (vol. 4 and 5)
RUSSELL, Clifford J. [1979], Collective Decision Making: Applications from Public Choice Theory (Baltimore: John Hopkins University)

SCHUMPETER, Joseph A. [1987], Kapitalismus, Sozialismus und Demokratie, Sixth edition (Tübingen: Francke)

SEMMLER, Willi [1994], Information, Innovation and Diffusion of Technology, *Journal of Evolutionary Economics* 4, 45–58

SMITH, Vernon L. [1962], An Experimental Study of Competitive Market Behavior, *Journal of Political Economy* 70, 111–137 (reprinted in: Smith [1991], 8–34)

—— [1964], Effect of Market Organization on Competitive Equilibrium, *Quarterly Journal of Economics* 78, 181–201 (reprinted in: Smith [1991], 35–55)

—— [1965], Experimental Auction Markets and the Walrasian Hypothesis, *Journal of Political Economy* 73, 387–393 (reprinted in: Smith [1991], 64–70)

—— [1976a], Experimental Economics: Induced Value Theory, American Economic Review 66, 274–279 (reprinted in: Smith [1991], 100–105)

—— [1976b], Bidding and Auctioning Institutions, reprinted in: Smith [1991], 106–127

—— [1982], Markets as Economizers of Information: Experimental Examination of the «Hayek Hypothesis», *Economic Inquiry* 20, 165–179 (reprinted in: Smith [1991], 221–235)

—— [1989, ed.], Experimental Economics (Aldershot: Edward Elgar)

—— [1991, ed.], Papers in experimental economics (Cambridge UK: Cambridge University Press)

SMITH, Vernon L., Gerry L. SUCHANEK and Arlington W. WILLIAMS [1988], Bubbles, Crashes, and Endogenous Expectations in Experimental Spot Asset Markets, *Econometrica* 56, 1119–1151

SMITH, Vernon L. and Arlington W. WILLIAMS [1983], An Experimental Comparison of Alternative Rules for Competitive Market Exchange, reprinted in: Smith [1991], 172–199

SUNDER, Shyam [1992], Market for Information: Experimental Evidence, *Econometrica* 60, 667–695

TREBEIS, Orestes V. [Horst Siebert, 1979], Nationalökonom*olog*ie (Tübingen: Mohr)

VARIAN, Hal [1992], Microeconomic Analysis. Third edition (New York: Norton)

WIHLBORG, Clas [1991], Arbitrage, Equilibrium and Market Efficiency. A Parable, *Journal of Economic Behavior and Organization* 15, 297–301

WILLIAMS, Arlington W. [1979], Intertemporal Competitive Equilibrium: On further Experimental Results, *Research in Experimental Economics* 1, 255–278

—— [1980], Computerized Double–Auction Markets: Some Initial Experimental Results, *Journal of Business* 53, 235–258

WILLIAMS, Fred [1973], The Effect of Market Organization on Competitive Equilibrium: The Multiunit Case, *Review of Economic Studies* 40, 97–113.

WITT, Ulrich [1992a], Evolution as the Theme of a New Heterodoxy in Economics, in: id. [1992b], 3–28

—— [1992b], Explaining Process and Change: Approaches to Evolutionary Economics (University of Michigan Press)

WORKING, Holbrook [1958], A Theory of Anticipatory Prices, *American Economic Review* 48, PP 188–199