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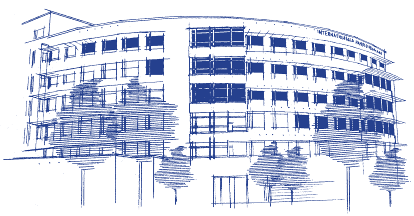
ESKIL ULLBERG

JÖNKÖPING INTERNATIONAL BUSINESS SCHOOL
JÖNKÖPING UNIVERSITY



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FROM PERSONAL TO IMPERSONAL EXCHANGE IN IDEAS:
An Experimental Study of Patent Markets with Transparent Prices

Eskil Ullberg*

*Interdisciplinary Center for Economic Science (ICES),
George Mason University,
CESIS, Royal Institute of Technology (KTH) and
Jönköping International Business School (JIBS)

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FROM PERSONAL TO IMPERSONAL EXCHANGE IN IDEAS:
AN EXPERIMENTAL STUDY OF PATENT MARKETS WITH TRANSPARENT PRICES

Eskil Ullberg, Interdisciplinary Center for Economic Science, George Mason University

Abstract

The question of how prices on patents rights should be determined in impersonal exchanges is examined in a laboratory environment. Dynamic gains from such organized trade with public prices are recorded. The experiment introduces a competitive market with impersonal exchange mechanisms and prices in the traditionally hierarchical and personal exchange of patents. A tradable linear contract (fixed fee plus royalty) is investigated with three mechanism designs for demand-side bidding and two levels of presumed legal validity of the underlying patent. A "trader" can split contracts useful for multiple "industries," creating dynamic gains, potentially increasing the use of technology in the economic system. Previous research on licensing has mostly been limited to one-dimensional auction mechanisms or static environments. The results indicate that agents appear to price the blocking value in the fixed fee and the investment value, net what is paid in fixed, in the royalty component, supporting a proposed theory of prices. Risks are thereby shifted from the invention to the consumer by means of this producer market, increasing the incentives for investment in invention, potentially resulting in a more competitive technology being developed and a more efficient economic system. The results give indications on proper integration of information and rules for mechanisms for organized market on patents with transparent prices. It also shows that intermediaries (traders) are critical to achieve dynamic gains from the system as are high presumed validity of patents.

1. Introduction[1]

In this article I wish to examine trade in patents in their own rights in organized markets with transparent prices. The economy has always been an "intellectual property" economy based on specialized agents trading products and services, using different mechanisms to keep the knowledge needed to produce private, but through the patent system knowledge[2] has become tradable[3]. The patent system changes the structure of economic organization by potentially introducing a competitive market in technology through the transferrable and licensable right on the technical ideas themselves. Such a market creates a dynamic economic system where

[1] The article, primarily concerned with the dynamic outcomes of trading patent rights in an experimental economic system, arose out of the study of management of risk and uncertainty through new market mechanism designs at ICES-GMU, and is part of a broader research on markets in IPR or "markets in ideas". See ULLBERG, E. (2009) From Personal to Impersonal Exchange in Ideas - Experimental Study of Trade in Organized Markets for Patents. *KTH TRITA-TEC-PHD 09-006***,** 180. Special thanks are expressed to the Savings Banks Research Foundation and Dir. Rodriguez for funding this research, The Royal Institute of Technology in Stockholm (KTH), and numerous personal communications with Prof. V. Smith, S. Rassenti, D. Porter, O. Hart, as well as input on market design from Goldman Sachs.

[2] Technichal ideas and, in the US also non-technical ideas, can be patent protected for products and processes.

[3] The patent systems typically give the owner two rights: to exclude and to transfer or license the right. It is the second right, to transfer or licence, that is a focus in this study.

increases in the stock of technology and focus for technology (technical area) are a result of competitive demand-side bidding, as bidders express their value for the technology resulting in transparent prices. Such shift in the focus of economic organization can be expressed as a shift from a personal to an impersonal exchange in ideas, a process that got started with the first patent system in 1474. This change made private technology both public through disclosure (a social exchange) and tradable (a market exchange) through an excluding, and transferrable and licensable right on new technology[4]. In the article the focus will be the "last step" in this transition towards impersonal exchange.

An experimental and dynamic economic system design was developed in an my earlier article (Ullberg, 2010c). This model, developed for a broad range of *market and social exchange* studies on patents, will here be used with an experimental design to begin to investigate some of the questions central to impersonal exchange: transparent prices of license contracts on patents (given different institutional arrangements, investigating the proper integration of information and rules) and dynamic gains from exchange (in terms of maximizing the use of technology in the economic system). The study is a joint study of the traded contract and market mechanisms for trading patents in organized impersonal markets with transparent prices in a dynamic economic system, where the patent validity is varied ("high" and "low" validity). This results in a 3 x 2 design. The social exchange in the economic system is explored in a setting of a broader coordination of demand for technology and investment with certain technology focus in a second experiment whose results are documented in (Ullberg, 2010a).

The key question addressed in the experimental design are (i) mechanism designs (whose price outcomes are compared to that of the proposed price theory), (ii) a heuristic analysis where the different designs are compared with respect to differences in prices and what can be learned from the incentives they give (giving information on proper integration of information and rules for this kind of market and social exchange), (iii) dynamic gains given the designs and patent validity (the dynamic outcome / optimal social dynamic outcome), and (iv) change in risk in the economic system (measured as a calculation of cost of capital in the system as activities are coordinated through prices)

Before discussing the trading system I state briefly the principal findings: (i) The (linear) contract prices appear to shift the risk-bearing away from the inventor to the innovator (and as a result ultimately to the consumer) in a way that supports the proposed informal price theory (best in an institution with two-dimensional bidding), (ii) reducing the risk in inventive activity as such which is likely to increases the competition in technology and (iii) the dynamic efficiency (the use of technology in new innovations) is at least doubled by introducing demand-side bidding on contracts for patents.

A short summary of the model (trade system), prices theory and approach (mechanism designs) described in the referenced article is first done as a background to the experiment (section 2, 3 and 4). For a more detailed explanation of these considerations see (Ullberg, 2010c). This will be followed by a description of the implemented dynamic microeconomic system model for the experiments (section 5), the experimental results, and some initial hypotheses (section 6). Conclusions on what has been learned about prices and dynamic gains, with possible policy and future research implications, will conclude the article (section 7 and 8). Some of the policy implications presented in section 7 and 8 and in the thesis are elaborated on–in summary form–in (Ullberg, 2010b).

[4] Typical criterias of patentability are that the technology has to be: new, nonobvious/have a sufficient inventive step and be useful/have industrial applicability. This excludes scientific formulas, and for the most part non-technology (with exception of business process in the US).

2. The patent system as a trade system

The economic system design is based on the *principles* of the patent system in order to make conclusions more relevant for policy. The problem of trading patents is here focused on *impersonal* exchange, i.e., a mechanism design problem, for a linear contract, in an environment with dynamic gains (multiple use of technology), uncertain technology values, and only presumed legal validity of the patent (uncertain patent rights). Two questions arise: how the prices should be determined on patents in a dynamic environment (the market studied is thus a producer market for technology), and how dynamic gains from trade may contribute to the value of the patent system. Impersonal exchange markets for patents are unknown; no formal exchange exists to date[5], and it is almost impossible to get reasonable information about how such a market could work (most personal exchange contracts are private with private prices). Therefore, an experimental economic approach is chosen as method of study.

The patent system is used in a complex manner. It is currently an almost global system but is in nature national/regional, with fundamental importance to national economies and trade agreements. It is increasingly used by an ever-broadening range of individuals, firms, and nation states[6], and also encompasses an increasing range of patentable subject matter, which in recent decades has expanded (to some extent) to include non-technical areas such as financial and internet-based services. This broad use makes it “inseparable” from economic activity today[7]. The approach chosen in this experiment to deal with the complexity is to take the *principles* on which the patent system is built as a basis for an economic system design and study one central aspect: the trade aspect, i.e., prices and possible dynamic gains from trade. A patent system relies on few, but powerful, legal principles: public disclosure of what is invented, the private right to exclude, transfer or license, the priority date for the invention, and national treatment, i.e., non-discriminatory treatment of international inventors[8].

This development of property rights in technology in history has also affected the organization of economic activity related to inventions, changing it from a single hierarchy *toward* coordination between agents in a market with prices. Specialized inventive firms have appeared, trading their ideas through personal exchange of patent rights. An early example of this was already observed after the 1832 patent reform in the US, where a market for technology developed for some time (Lamoreaux and Sokoloff, 1999). Since the 1982 decision, a high growth in patent licensing has been observed, especially in new technologies, which reaches perhaps $1tr annually[9] with different kinds of specialized firms, from pure inventing to joint ventures. Likewise, new types of agents have developed, such as patent portfolio holders[10]. Most of these trades take place as a personal (and bilateral) exchange between firms with a few exceptions of initial impersonal exchange through public auctions (multilateral bankruptcy auctions and specialized auctions).

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[5] An almost explosive development in patent licensing has been observed over the last 25 years, after the 1982 change of the US patent system. A similar trade in patents was observed after the first US patent law in 1832 (Lamoreau 2001). Recently fixed price auctions of patents have successfully been run by some private specialiced firms.

[6] Local inventors, university professors, inventor companies, governments and banks/Venture Capitalists as collateral for debt, etc.

[7] Similar comments can be made for other intellectual property rights covering other areas like: trademarks, copyrights, geograhpical indications, etc (WTO/TRIPS have currently 7 types).

[8] There are also some exeptions related to risks for social unrest, which in fact are caveats of the system.

[9] This is an estimate many patent lawyers make.

[10] This business model opens the door for a new use of capital—to trade technology. These agents bridge the time between invention and innovation and capitalize on the maximum use of technology. This business model is thus incentive compatible with social gains. Such a use of capital is incorporated in the experiment as “traders” who take positions in a contract, split them, and sell two new contracts.

The principle used in the experiment is coordination of agents performing inventive, trading, and innovating activities through a market with prices. The division of these agent characteristics is motivated by their respective riskiness, as expressed by the cost of capital.

3. Summary of a price system on patents

This summary is based on the previous model article. There are two problems to be solved by a pricing system: (1) how much money each agent shall have; and (2) the system of prices (mechanism) in accordance with which the contracts are to be made available to the buyers[11]. In this experiment, the first question is addressed with an endowed discount rate (cost of capital) to calculate the value of a contract; and a role-specific exchange rate of experimental dollars to paid dollars intended to, in principle, make each role equally profitable[12]. The second question is the main question of investigation.

Firstly, the mechanisms represent the terms under which an agent can obtain a contract. For fixed-price contracts "the same factor (contract) should have the same price in whatever use it is employed since otherwise customers (agents) would not be able to choose rationally, on the basis of price, the use in which they prefer a factor (contract) to be employed." (Coase, 1946) (words in parentheses added). However, in the case of the patent, it has *two* values depending on its strategic use as discussed in the model article: an investment value and a blocking value. The values differ considerably with respect to (market access) risk. Investing is a high cost, high uncertainty activity that provides the holder with a possible long-term competitive advantage, and, therefore, long-term market access from *new* products and processes. Blocking, i.e., "sitting on" the contract, is typically a rather low cost, low uncertainty activity that provides the holder with an "insurance" against short-term loss of competitive advantage and market access to *existing* products and processes based on other existing technology held by the firm. These values clearly have to be dealt with separately in a pricing system where rational choices could be made with respect to its use, since the price of a fixed-price contract otherwise would yield different prices depending on its use.

Blocking allows the holder to block competition (temporarily), or to better time its own investment decisions, in order to avoid cannibalization of its own market share, avoid retiring productive assets, or make other possible strategic decisions with respect to research. In the referred article, the proposition is made that blocking is formally similar to an insurance contract (in this case, insurance against irreversible loss of sale (revenues)) and could be *priced* as such. This suggests that the blocking value could be priced with a fixed price, since the risk is more or less predictable and therefore "insurable" and transferrable.

On the other hand, the high uncertainty of the investment value is typically not predictable in any way similar to blocking. The risks are not "insurable", nor transferrable (since it is hard to put a value on them ex ante their use in an innovation). The proposed solution here is a risk sharing arrangement based on a royalty. We here borrow from investment theory and propose that the net present value (NPV) of the investment value *minus* the paid fixed price (attributed to the blocking value) would be paid as long as it is positive. A royalty on sales (revenues) would here be possible, based on the realized usage of the contract, thus a price is paid when the risks have become known. This makes the royalty an "investment option" type of arrangement.

These propositions to price the blocking and investment values differing with respect to risk, thus lead to a linear contract with a fixed fee and a royalty component. The proposed

[11] These criterias of a pricing system is made with reference to COASE, R. H. (1946) The marginal cost controversy. London School of Economics and Political Science.
[12] The motivation behind this is that subjects be equally cash incentivised in any role in the experiment.

contract leads to a multi-part pricing system. The characteristics of a pricing system for patents (legally defined as "chose in action") thus sharply differ from those of potatoes and shoes ("chose in possession"). This type of contract is a contract commonly used in patent licensing and preferred among inventors, although it appears difficult to obtain a fixed component in existing personal exchange environments[13]. Ideally, these two values should therefore be priced independently in an auction mechanism. Therefore, coordination between specialized agents should, in order to capture both values, also be able to price these values independently. The proper integration of information and rules will be investigated in three different mechanism designs in this experiment.

Secondly, a criterion for a system of prices is that the price should be the same for all agents. This means that the *highest bidder* would get the contract. For a traded commodity, this means that supply equals demand, i.e., the price is an equilibrium price. For an exclusive contract with discrete values, of which there is only one available, this means that the expected price should equal the *second-highest* value plus epsilon (Bertrand competition). Since the blocking value can be "immediately" realized by whoever is sitting on the contract (it can be sold to a "blocker"), it is a more "common" value[14] than the investment value. Following this reasoning, the market access value for blocking must therefore be paid by the investing user as well. The consequence is that with the proposition for a theoretical "equilibrium price" for the contract on a patent where the fixed price then equals the second-highest blocking value plus epsilon and the royalty price equals a royalty that keeps the NPV positive, at the given discount rate, for the second-highest investment value plus epsilon, minus the blocking value[15]. The prediction is under the condition that the *same* agent has the both the highest blocking and investment values. If these are different agents then the prices will be *between* the highest and the second-highest values in a combination that depends on the size of the blocking and investment values in NPV terms. These "mixed" price predictions are not investigated in this experiment.

The clearing of a linear contract thus is not a simple transfer of an asset like in the typical single-price auction market, but an allocation of risk-bearing and sharing negotiated *in* the fixed fee plus royalty price. This differs from the traditional analysis of asset pricing where the risk-bearing is separated from a transfer price through derivates on the state of nature (Arrow, 1962a) (Arrow-Debreu securities). The two-dimensional price is tested in three market mechanisms.

4. The mechanisms design criteria

The division of characteristics of the agents has been done with respect to these activities' typical riskiness and mimics the activities typically coordinated in a firm hierarchy by a general manager (research, finance and market, with the general manager being replaced by the patent market with prices). The focus of the design is in the *during*-patent time trade and use of privately owned but publicly disclosed technology (pricing of the linear contract and dynamic gains from trade), not the *pre*-patent time private research (ex. patent races) or *post*-patent (ex. spill-over) use of public technology. The economic environment is the controlled

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[13] Data obtained courtesy of RoyaltyStat LLC, which holds a database of 8000+ licensing contracts with 3000 patent licenting contracts, indicates that only 50% of contracts have a fixed component. 12% have milestone payments, 24% a lumpsum payment, and 13% a minimum payment.

[14] The meaning of "common value" may need to be clarified further for the patent case. Here it is used with reference to a value that is commonly expected among all agents through experience with similar technologies.

[15] In a situation where there are several inventors and competing technologies for sale, a multi-contract market in ideas, an equilibrium price would form where the risk in the different technologies is taken into account.

environment, and the institutions and legal environment are the independent variables in this experiment. Values for the contracts are induced and uncertain (given in a range) and different agents have different values with one having the highest value (to investigate the allocation mechanisms). The type of patents examined are product patents, adding revenues by adding "features" to existing products, in contrast to the small cost-reducing process patents often used in the traditional analysis.

The differences between the institutions are the messages and information, as well as the rules under which a *buyer* can respond to a seller. The buyers face the decision to use either both (fixed fee plus royalty), one (royalty), or none (accept/reject) of the linear dimensions to negotiate a price. Thus, they are more or less constrained in expressing their willingness to pay (WTP) for the two values. In the first case, they can fully express their WTP. In the second, for all practical purposes only the royalty can be used. Finally, in the third case, they can only accept or reject an offer posted by the sellers. The sellers can always express their willingness to accept (WTA) using both dimensions. The third institution is close to personal exchange and the others more impersonal exchange. Differences in prices and dynamic efficiency here would suggest possible gains in the economic system given a shift in trade toward a more impersonal exchange system for patents.

These different mechanisms are thought to be useful in studying integration of information/messages and rules for demand-side bidding mechanisms. For the purpose of this study, the mechanisms should reflect agents' pricing behavior in solving the two-dimensional value problem faced (block/invest), using a *linear* contract to price them (fixed fee plus royalty). The behavioral question is therefore how the human subjects would express the two values in the two-dimensional price. The hypothesis is that they would do this according to the different risk inherent in the two values.

5. The mechanisms: Details of the institutions, the economic, legal, and insurance environments

The trading procedure employed in this study is a specially built computerized trading system[16] for linear contracts that incorporates the three institutional mechanisms tested (the primary markets), individual screens for the Inventor (Role1), the Trader (Role2), and the two types of Innovator roles (Role3A and Role3B), as well as a fixed price double-auction mechanism (the secondary market) used to re-trade the contracts already negotiated in period 1 in periods 2 and 3. There are thus three periods in each round. Appendix 1 provides the participant's screen displays for the different roles. An instruction-set used during the experiment allowed participants to learn the interface more quickly by providing each participant with a detailed explanation of the different areas, boxes and information on their screen and what each role could do.

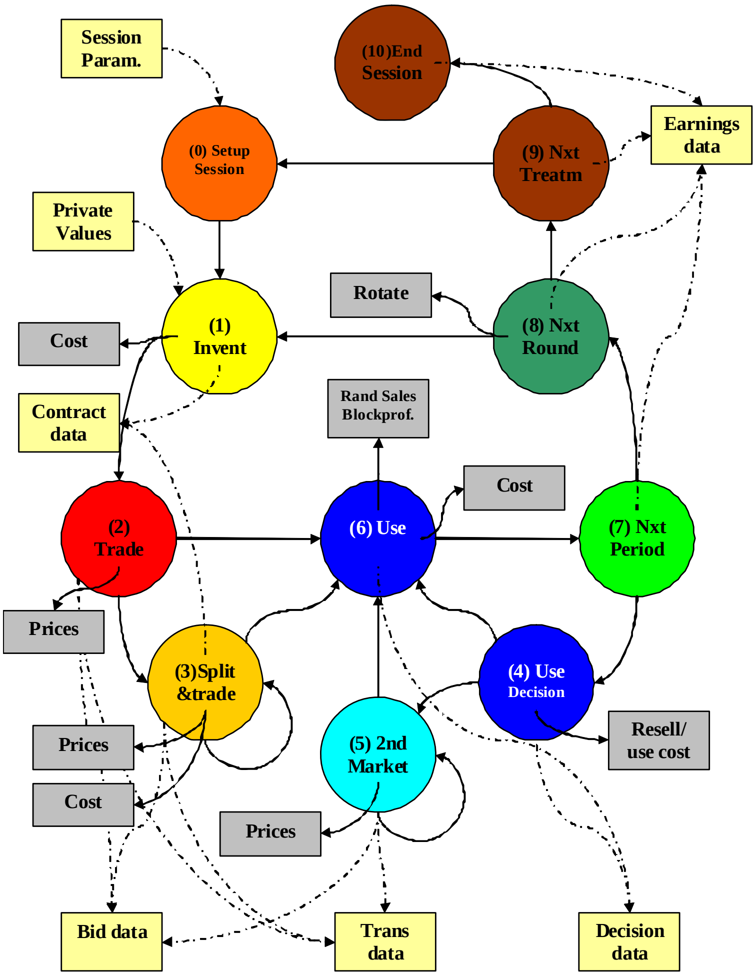

Fig. 1. – State diagram of the endogenous experimental flow in the experiment.

16 The software was developed by the author, except the network messaging module used at ICES for many years. A significant part of the total time in this project was dedicated to developing the trading environment. Special thanks to Lance, a software consultant to ICES, who came up with a key concept to solve the complex endogenous experimental sequence (a state machine) at a critical time in the project. Without that solution concept the author would probably still be programming… The ICES message module was developed by Jeff Kirchner at ICES who also willingly gave input on technical programming issues. Finally, thanks to Will Christie who gave input regarding the computer language used and also made the computerized instructions for the pilot.

The endogenous experimental flow

Fig. 1. gives an overview of the state diagram of the endogenous experimental flow in the experiment. The experimental flow follows three general "phases" or steps which are repeated in each round: Inventive step (1), Trading steps (2) (3), and Using steps (6) (4) (5). The actual flow is then executed by the decisions of the participants. The Inventor is first asked to create a linear contract of "standard" or "quality" type (1). The contract is predefined as a license on an invention with "technology focus" "AB," useful for producing products of type "A" and "B." A quality contract can be split into one contract with focus "A" only and another contract with focus "B" only. The trader is the agent who can split the AB contract into the A and B; thus, a quality contract allows the Trader to participate in the bidding process (2). If the inventor decides to invest in a standard contract, which cannot be split, the Trader is left out of the bidding (2) for that round. If the Trader wins the AB contract, and then subsequently splits it, the A and B contracts are sold in sequence to the Users of Role3A and Role3B respectively with the Trader now being the seller and the Users the buyers (3). A User of type A can only produce products of type A (their "product mix") and vice versa for type B Users. If a standard contract is sold, all Users can thus participate but there will be only be one winner and one participant (A or B type) who can use the contract. If the contract is split, there are two participants (A and B type) who can use the two contracts.

The contract(s) sold thus eventually end up in the "portfolio" of one User (with product mix A or B), or two Users (one with product mix A and one with product mix B) and a Trader (who holds the AB contract issued by the inventor). The User(s) holding the contract(s) are now asked (6) to either "Invest," which produces a profit based on increase in sales of the new more competitive product(s) A and/or B invested in, or to "Block," which produces a profit based on the existing sales of the product(s) based on existing technology the firm has been endowed with, "insuring" the firms market access against competition based on technology. The sales and blocking profits are randomly drawn from a uniform distribution from the holders induced value range and displayed to the participant if "Invest" is chosen (since the issuer should know the basis for the royalties), after which period earnings are calculated for period 1 and the experiment moves to the next period (7).

At the beginning of period 2 and 3 the holder (4) is given the possibility to decide to resell the contract (or keep the contract), which starts the secondary market (5); then, if the contract is resold, the new holder is asked to use it (6) (cannot resell until next period). If the holder decides to keep the contract, then the holder is asked how to use it this period (6), after which the sales/blocking profits are randomly drawn anew within the respective value range, and period earnings are calculated for all participants who held (bought/resold) or issued (sold) a contract, ending period 2. Period 3 proceeds in the same manner as period 2. At the end of period 3, total earnings are calculated for the round and the next round is started (8). In this round, the roles may be rotated among participants with some frequency (for example every 2 or 3 rounds).

The trading screens

The participant's screens are rather complex "trading screens," but follow the same theme and logic as described. The screens sections cover private, public, and earnings/status information, useful for the participant in making decisions. The private values and other information on the contract are given at the beginning of each new round. The values are given in ranges for the three periods. There are thus 6 ranges (3 for sales increase if the contract is invested in and 3 for blocking profit if the contract is used to block). Once role 1 has decided the quality of the contract[17]—technology focus cannot be changed in this experiment—roles 3 and 2 (if a quality contract) will have their private values displayed. The public validity and quality, as well as the private discount rate for the contract, are also displayed with the values.

In the first mechanism, similar to a two-dimensional version of a double-auction with free bidding (referred to as institution DA-rule1), participants enter a linear price to buy (or sell) the contract by entering their fixed fee and royalty bid (offer) and then clicking on the button labeled "Send Bid" (or "Send Offer"). Participants can also accept any other participant's bid to buy (or offer to sell) by clicking on the button labeled "Accept Bid" (or "Accept Offer"). The acceptor must then confirm the acceptance by clicking "YES" (or "NO" to cancel the bid) on a pop-up box. This results in a binding contract being formed and the exchange information being recorded in the public market information section on the interface. Also, all past transactions are listed with the last transaction first as a memory for the participants regarding negotiated prices for the different markets (primary market AB, A, B, resell price, validity, and quality). The participants are given calculation tools to automatically calculate expected profits, given their expectations of the outcome in the value range and whether investing or blocking is chosen. A "sliding ruler"—scaled from 0 to 100%—is used to input values from the included *ranges*, periods (1-2-3), and uses (invest/block) into the calculator. The selected *expected* values are displayed below the value ranges and next to the entered quote and calculated expected profits. Expected profits are calculated in real time to allow the participants to test different expectations and combinations of fixed and royalty bids *before* submitting their quote[18]. The arrangement allows for studying the risk behavior of the subjects (risk-averse, risk neutral or risk taking).

Price quotes must reduce the bid-ask spread in one or both dimensions in order to be accepted. A buyer can ameliorate a bid, for example, by increasing the fixed bid without increasing the royalty bid. The five highest bids and lowest asks are displayed in a ranked order visible to all participants. Only the highest bid and the lowest ask are open for acceptance. Price quotes that violate this rule are rejected. Identical bids are thus rejected (since there is only one license for sale). The auction is always started by the seller (a role1 or role 2) and ends when the bid and ask meet in both dimensions, an "accept" is made, or the auction is timed out, which results in a "no trade" for that contract. In the case of "no trade," the seller has to bear any costs associated with the creation of the contract (role1) or loss of fixed and royalty fees to cover cost against obligations from the contract bought (role2). Buyers are not affected by a "no sale." The time-out function has two timers to speed up the bidding process: one for the maximum total time for the auction (usually 120s) and one for the maximum time between bids (usually 20s).

The second mechanism, double-auction with reservation value on the fixed component (DA-rule2), is identical to DA-1, except with regard to the amelioration rules. The seller can only *increase* the fixed component, i.e., the initial fixed quote is a *minimum* not a maximum. The buyer can only decrease the fixed bid, i.e., their initial fixed quote is a *maximum* not a minimum. The royalty bid works the same way as in DA1. This institution thus gives the seller the privilege of setting a binding minimum price on the fixed fee, which can be interpreted as a reservation value. Only the royalty can be negotiated downward. Bids cannot "cross" thus when for example the fixed bids meet; only the royalty can be negotiated further

[17] In the reported experiment, the inventor's technology focus ("AB") and the user's product mix ("A" or "B") are fixed; only tradability (quality) of contract can be decided. In a second experiment, the technology focus or the contract can be engogenously searched from a limited "search space."

[18] In the initial sessions, the "sliding ruler" was not implemented and the participants manually entered their expectations, a time consuming task but with the same result on the calculations. The slider greatly speeded up the trading process and the possibility to quickly check expected profitability of one's own quotes as well as market quotes. "Subjects should make decisions, not calculations." (B. Wilson).

or vice versa. The same market information is given and the auction starts and ends in the same way as DA1.

In the third mechanism, repeated posted-offer (PO), or "manual Dutch Clock auction," the seller enters a price quote in exactly the same way as in DA-1. However, the buyers are limited in bidding space to a simple accept or reject of this offer by clicking on the button labeled "Accept Bid" or "Reject Bid." The information on who or how many have accepted or rejected the offer remains private. If all buyers reject the offer during a bidding round, then the seller can ameliorate the offer by reducing the quote in one or both bidding dimensions just like in DA-1. Such amelioration comes at a cost for the buyer. The bid-ask gap is unknown to both buyers and sellers until the quote is accepted by at least one buyer, at which time the binding contract is formed. The auction ends when the *first* buyer accepts the quote in the bidding round or there is a timeout. This mechanism could perhaps therefore be called "manual Dutch Clock in two dimensions" where the "clock ticks" are provided by the seller's reduction in quote in every bidding round. Only the past offers are listed in a ranked order in the public market information.

The secondary market (5) is a standard fixed price double auction (FP-DA) common in asset experiments where the seller enters a fixed price quote for the contract in its portfolio, bought in a previous period. The contract terms (fixed plus royalty) agreed upon in the primary market (2) or (3) are not re-negotiated but the contract is transferred "as is." Price quotes can be positive (seller gets money from the buyer) as well as negative (sellers pay money to the buyer). This mechanism allows for already-negotiated terms to be compensated for to a level acceptable to a buyer. The buyer (sellers) can also accept the highest ask (bid), like in DA-1. Contracts can be resold in periods 2 and 3. The auction is started as the seller decides to resell (4). The first quote can thus come from either the seller or a buyer[19]. The quotes have to reduce the bid-ask spread. The auction ends when the quotes meet, an "accept" is made, or the auctioned is timed out. There is a timeout for the total auction time (90s) and for the maximum time between quotes (10s).

Trading occurs over a maximum of 30 rounds, each having three periods, lasting approximately 1-5 minutes each per round. The experimenter can end the session at any round (in order to limit the session time). Screen displays are updated in real time at any event resulting in change of private or public information.

Subject payments, endowments and special "rules of the game"

At the beginning of the experiment, initial roles are assigned to the participants. There is one inventor (role1), one trader (role2) and 6-8 users (role3), with half in "industry A" capable of producing product A, and half in "industry B" capable of producing product B (if an odd number of users is involved there is one less in industry B).

Each participant is endowed with a capital of experimental money at the beginning of a treatment. The purpose of the capital is to introduce "bankruptcy laws" and "loss aversion." The participants' earnings are decided by accumulated gains (losses) via contract issuing, splitting, and using contracts held in portfolio during each period. At the end of the experiment, participants are paid a weighted sum of accumulated earnings in each role plus an hourly fee fixed fee (for keeping the capital positive) and a fixed show-up fee (for showing up on time), not counting the experimental money capital endowment. The exchange rate is decided at the end of the experiment (partly due to time constraints on the number of rounds in each session), and "converged" to 0.1 for role 1, 1 for role 2 and 0.5 for role 3, in order to

[19] In the later experiments, the market starts by re-listing the contract and either the buyer or the seller can post a first bid/ask. In the earlier experiments, the market started once the seller sent in an ask. The change in procedure was motivated by time constraints for the experiment, and speeded up the re-sell.

make all roles approximately equally profitable, which turned out to be a difficult task for most agents.

If the accumulated losses deplete the capital, a one round grace period is given to the participant ("Chapter 11"). If the capital is still negative at the end of the next period the participant is declared "bankrupt" and cannot participate further in that session, and both the hourly fee and the show-up fees are lost (there is no payment for the session). This seemingly harsh measure was introduced to stop constant overbidding by many participants in the initial sessions, and it had the desired effect. After the rule was introduced, only one person entered "Chapter 11" and no one went bankrupt, although 2 came very close ((Compare (Kahneman and Tversky, 1979) on Prospect Theory and "loss aversion."). The importance of the rule in the experiment is that participants who are systematically overbidding "at no cost" destroy the market, which is precisely the dimension we want to study. Therefore, we needed to find a solution that gave sufficiently salient incentives for profit-seeking behavior. Simply paying trade gains was not enough (positive enforcement). It was necessary that participants lose something given to them, apparently inducing loss aversion behavior (negative enforcement). The capital endowment solved this problem beautifully. It was therefore not enough to have property rights to trade but also rules that limited the greed of some participants from destroying the market (Compare "Thou shalt not steal nor covet your neighbors possessions," and "declaring the fundaments of markets and a warning that distributional jealousy should not be allowed to destroy them." (Smith, 2002)).

Participants are informed in the instructions about the linear nature of the contract, the decisions and activities each role can do, the uncertain nature of the sales and blocking profits generated by using the contracts, and the "bankruptcy rules." They can keep the instructions with explanations of the trading screens and experimental flow during the whole session. They are not informed about the distribution of values among participants (which is a linearly increasing function).

In some initial experiments the secondary market was not used. Invalidated contracts annulled payment obligations (typical practice in real world). If a contract was invalidated, this information was immediately displayed in the market info box. The number of participants varied between 7 and 10 in all sessions, changing the competitiveness of the demand-side. Each session is reported separately and all data can be related to an individual.

6. Overview of experimental design, design parameters, market performance, and the sequence of the experiment

I report findings from 27 experimental sessions using the design parameters listed in Table I. A 3 x 2 design was used for the study of prices and dynamic gains under three primary market institutions and two levels of presumed patent validity (design 1-6). These were the independent variables. (Two special treatments (design 7-8, only briefly reported) were also run in order to test pricing under insurance (to cover for any loss of validity) and high investment demands (for investment decision).)

The induced investing and blocking value ranges were positive in most treatments exploring the linear contract for positive prices[20]. In two treatments (20.2 and 22.1) , investment and blocking values (with only one being positive and the other zero or negative) were used to create an economic environment of "boundary conditions" for linear prices. In about half the sessions there were two B-contract markets, randomly changing between the two values between rounds, designed to test "robustness" of the institutions[21]. The values for the investment and blocking values were given in overlapping ranges, linearly increasing for the buyers to create a competitive bidding environment with only one "high value" bidder, useful for evaluating allocation performance of institutions[22].

The inventor was given a broad range, spanning over the ranges of all buyers, a typical condition for inventors. The traders were also given the full range but spanning over each "industry's" ranges. This was based on the presumption that traders typically have better information than inventors, being closer to the product market. The users had the most narrow (precise) ranges of values being in the market using the technology. Trial sessions were run with valid (100%) contracts to verify institutional performance during the development of the final experimental design and some trial sessions (design 0). A fixed cost of capital, specific to each role type, was used to discount the values over the three periods in each round[23]. Past market experiments suggest that at 3-4 buyers are needed to avoid collusion (some would say 6-8). For the AB contracts, mostly 7-8 were bidding and for the A and B contracts, 3-4. The design thus permitted variation in the competitiveness of demand-side bidding. A homework assignment was given after the final session, asking participants to teach future participants what to think of when trading in the different experiments. The purpose with that exercise was to study what participants were *thinking* when trading, as one studies what subjects *do* in experiments.

[20] The linear contract allows "negative" prices in one or two dimensions. Negative fixed price means that the buyer is borrowing funds to explore the rights in the contract for a royalty including the value of the contract + the value of the money (debt). Similarly, a negative royalty means that the seller is paying the buyer for the effort of investing in the contract for a fixed fee including the usage value + the risk in the product market. For role 2, who splits the contract, positive prices in particular mean an injection of capital in the trade (a new use of capital). No voluntary trade was observed with negative prices.

[21] Ref. to personal communication with S. Rassenti for introducing the idea of a "robustness" test.

[22] The range was fixed in most experiments ("fixed risk"). In one experiment, 20.2, the range/midpoint value was fixed ("constant risk") to induce more risk for higher values. All realizations of values were done using a uniform distribution across the range.

[23] This variable was thus exogenous in this experiment. Typical cost of capital for the specialiced type of agents were used.

TABLE I

Design	Institutional and legal environment: Institution	Validity (%)	Competition: Type A and B users	Contract values: Mid point of high blocking value: *** (ABs; ABq, A, B/B+,-)	Values	Experiments	Data
0	DA-1	100	(4+4)	(8;8,4,8/8)	Values1	2p1,5p1	-
	PO	100	(4+4)	(8;8,4,8/8)	Values1	4p1	-
1	DA-1	100/93*	(3+3)	(7/8;7/8,3/4,7/8)	Values2	6,7,8,16p2	64
			(4+4)	(8;8,4,8/8)	Values2	15p2	-
		100/93*	(4+4)	(3/4;4,4,0/0)	Values3	9.1, 14p2	27
		100/93*	(2+2)	(2;2/3/4,4,0/0)	Values3	13p2	-
		93	(4+3)	(4/9/10;4/9/10,4,0/10)	Values4	17.1	25
		93	(3+3)	(7/12;7/12,3,7/12)	Values5	18.2, 19.1	47
		93	(4+4)	(8/14;8/14,4,8/14)	Values6 +	20.2	19
		93	(3+3)	(-5/7;-5/7,-5,-9/7)	Values7	22.1	38
2	DA-2	100/93*	(4+4)	(3/4;4,4,0/0)	Values3	9.2	14
		100/93*	(3+3)	(7/8;7/8,3,7)	Values2	10	10
		100/93*	(4+4)	(8;8,4,8/8)	Values2	11.1	24
		93	(4+3)	(4/9/10;4/9/10,4,0/10)	Values4	17.2	11
		93	(3+3)	(7/12;7/12,3,7/12)	Values5	18.1	26
3	PO	93	(3+3)	(7/12;7/12,3,7/12)	Values5	19.2	20
4	DA-1	38	(4+3)	(7/12;7/12,4,7/12)	Values5-38	21.1	34
5	DA-2	38	(4+3)	(7/12;7/12,4,7/12)	Values5-38	21.3	30
6	PO	38	(4+3)	(7/12;7/12,4,7/12)	Values5-38	21.2	12
Special							
7	DA-1	Rand. 93 or 38 **	(3+3)	(7/12;7/12,4,7/12)	Values8	22.2	22
8	DA-1	93	(3+3)	(-5/7;-5/7,-5,-9/7)	Values7 ++	22.3	11
							434

Cost structure:
Issue cost: Standard contracts 1 and Quality contracts 5 for experiments 2 - 10 and 2 from experiment 11-22.3
Transaction cost: 0 for experiments 2 - 17 and 1 for experiment 18 - 22
Use cost: Variable cost = 60% of sales for experiments 9-17 and 65% for all others
Insurance cost: 25% for experiment 22.2 and 0 for all others
Cost of capital: 30% for Inventors, 5% for Traders, 10% for Users
Patent renewal cost: 0
+) The blocking value range/midpoint is constant in this treatment (constant risk).
++) Investment: 11 for session 22.3 and 1 for all other sessions
*) validity alternated every 5 periods starting with 100%.
**) validity randomly changed between 93% and 38% plus choice to buy validity insurance
***) The values are given in a range (a,b) to the subjects and a random value is drawn for the realization of the value using a uniform distribution. Other distributions like Poission may be used in future experiments. The midpoint in the range is here shown for the different markets (contract type ABs,ABq,A,B). Quickly common expectations were created for the contract value. In sessions 17-22 there were two alternating blocking values used (separated by the '/') for the AB and B contracts, creating a "two-commodity" market to study robustness in the instiution with respect to pricing on fundamentals.
In Exp 1-8 some ABs/q values vary due to rotation among agents with less than 8 on the buyer side, dropping the highest value.
p1, p2) practice/training sessions for team 1 and team 2. Two teams were used to compare. No real differences were found.

Before the data collection experiments, a prototype test was run testing the *feasibility* of trading a linear contract with uncertain values. The prototype did not include a trader role but simply tested, successfully, the core of a market mechanism with two-dimensional simultaneous bidding. A special software was developed for this test. After that, a complete parameterization and systemization was made for a first *pilot* set-up. A second software was developed, this time including the trader role. This tested the dynamic trading including the trader and showed that the dynamic environment actually worked (the trader was able to trade and split a contract). Finally, a *design* and a third, complete, software was developed for the reported experiments. The first experiments were used as training sessions. Previous experience with complex environments suggests that the experience level and information state of subjects is critical to eliminate the possibility that results are sensitive to these factors[24]. See Appendix 1 for the recruitment process and a copy of the instructions aimed at qualifying subjects as well as get accustomed to the software. The first sessions thus served as *subject qualification* sessions, perfecting the software for the trading environment, the design and instructions.

Data for value expectations, bids, time series, prices, dynamic gains and other dynamic system parameters were recorded. A brief visualization of the dynamics in the price adjustment process and of subject's value expectations (risk preferences) is summarized first. The focus is then on the clearing prices and, as a consequence of this impersonal exchange, dynamic gains from trade. Experiments with high validity are reported first (design 1-3), by institution and market, followed by the experiments with low validity (design 4-6).

6.1 Market performance and dynamic gains under high validity

6.1.1 Some observed market dynamics in price clearing in the primary markets

The bidding process is visualized in Fig. 2-7 for the three market mechanisms: DA1, DA2 and PO. The process clearly suggests that the bidding takes place in both dimensions. Three examples are given. In Fig. 2., (ABq/B contr., Session 8) the clearing price is paid in fixed fee and royalty that exactly matches the induced blocking and investment values respectively. The figure also illustrates a "linear" bidding process, i.e., the buyers and seller tend to adjust both dimensions to agree on a price. In Fig. 4., (ABq/B contr., Session 19.1) the buyers are reluctant to accept a high royalty asked by the seller but in the end bids jump to meet the royalty demand. However these royalties are at unprofitable levels for investing, indicating that the buyer is intending to use the contract to block. The fixed component clears at just below profitable levels for blocking. In Fig. 3., (ABs contr., Session 19.1) the opposite happens. The seller eventually drops to clear the price at a lower royalty, but profitable level for investing, presumably intending to invest. The buyers here appear to signal their intentions by the dimension in which they prefer to increase their bids.

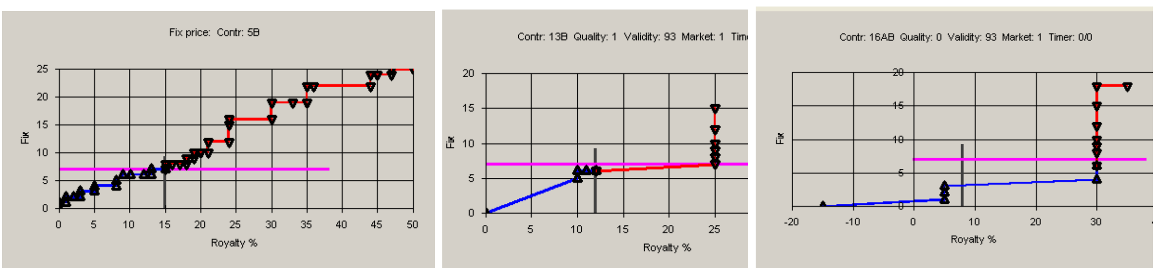

Fig. 2-3-4. Examples of the bidding dynamics and price dynamics data for DA1 from session 8 and 19.1. Triangle pointing down is an ask, a triangle point up is a bid, and a star is the clearing price. The horizontal line is the theoretical fixed price and the vertical the theoretical royalty if the theoretical fixed fee is paid.

[24] Special thanks to Prof. Vernon Smith for discussion on the importance of pilots and training in complex economic "real world like" environments prior to data collection. Several pilots were run to verify the economic system design (prototype), the experimental design (pilot) and procedure, software, interface and instructions (training sessions).

Similar patterns can be observed in DA2 but with considerably less negotiation. Fig. 5. (ABq/B contr. Session 18.1) shows how the seller sets a reservation value on the fixed fee and then negotiation takes place in the royalty, until the clearing price is profitable for the buyer. Fig. 6. (ABq/B contr. Session 18.1) show how a high, and clearly unprofitable, reservation value on the fixed fee is traded-off for a lower royalty when profits can still be made from investing without having to accept a negative royalty (never observed). All these contracts were also used for investing. Fig. 5.-6. also illustrate how a *trader* outbids the users using the fixed component (Fig. 6.), then sells at a lower fixed fee, but a higher royalty (Fig. 5.), apparently attempting to trade off risk-taking (accepting a high fixed fee for contr 20AB, Fig 6.) for risk-sharing (asking a lower fixed for split contr. 20B, Fig. 5.).

A different pattern is observed for PO. Fig. 7. (ABq/B contr. Session 19.2) which shows a sequence of take-it-or-leave-it offers where the ask is ameliorated once prior to being accepted. In this case the contract is actually accepted at a loss for the buyer if blocking, making investment the only profitable option. These very short negotiations (often only one ask) typical for the PO, often led to a slight under-pricing of the contract (there was a cost of ameliorating the bid).

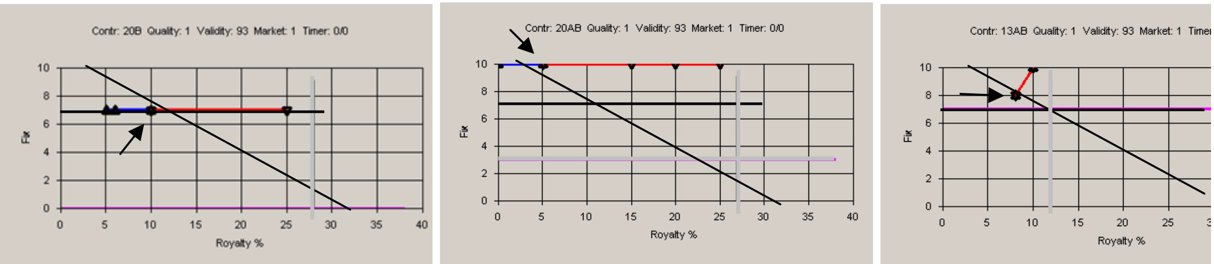

Fig. 5-6-7. A example of the bidding dynamics and prices dynamics for DA2 and PO. The vertical and negative sloped lines indicate limits to profitable price for blocking and investing use.

During a session, prices tended to converge over time. This indicated that a sustainable (stable) trading pattern had been established for the dynamic economic system. Such a system end-state (a Nash equilibrium) is used to compare the institutions. In Figure 8, data for DA1 from session 6 are plotted for the fixed and royalty prices as a function of time (ABs, ABq/B and A contracts). Adding a log-trend to the data points gives indications of convergence towards the prices proposed by the informal theory for this institution.

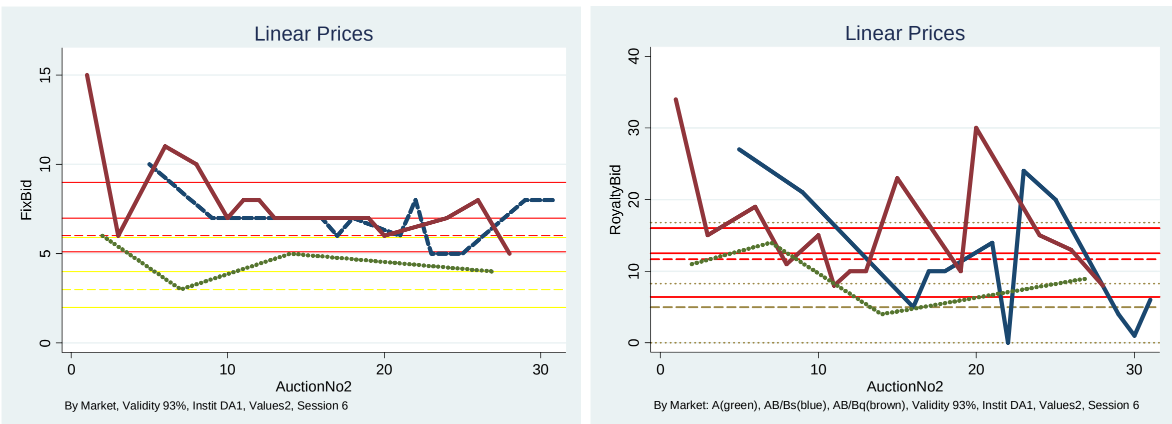

Fig. 8. – Price convergence for fixed and royalty. The solid line (upper) is the B/quality, the dashed (middle) the B/std and the dotted (lower) the A contract. Horizontal lines indicate the induced value ranges for the highest value and the dashed lines indicate the predicted competitive outcome.

The fixed prices are generally less volatile than the royalty prices. This can be explained in part as a trade-off with the fixed. The average price of the fixed is "epsilon" higher than 6, which equals the theoretical prediction. The contracts appear to be priced near predictions. Fixed prices clearly converge to the second-highest blocking value. The royalty price appears to converge on average but is much more volatile.

Contract values were also varied randomly between a high and a low B-contract value (the "robustness test"). Fig. 9. illustrates the ability of the DA1 institution to price the contracts according to fundamental value (session 18.2). A separation between the B, B+ and A contracts can be seen in the figure, again with a trend to adjust to the theoretical predictions, especially for the fix. The B+ contract royalty prices are higher than expected. These contracts were mostly used to block; thus, no royalty had to be paid, a subject I will come back to later in the analysis.

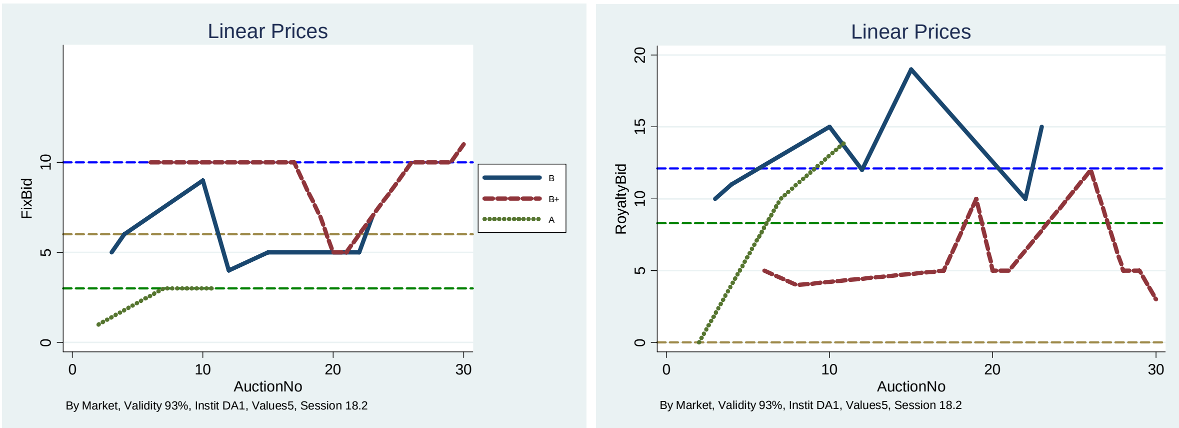

Fig. 9. Price convergence for two randomly alternating values for the B market. The upper line is the B+, the middle the B, and the lower the A contract. Dashed lines indicate predicted competitive outcomes.

These examples of initial results appear to support a separation of fixed and royalty prices tied to the blocking and investment value and usage in particular when both dimensions are up for bidding (DA1). Different types of trading patterns were observed for the different institutions but these are not reported here except through these examples.

When making their bids and asks, the subjects were asked to decide on the expected outcome of the random draw in the value range (0% - 100% in the range). These expectations were used by the subjects to calculate expected profits from a contract if acquired at the current bid (a calculation tool helped subjects to keep the focus on making decisions, not calculations). An analysis of 116 transactions (session 21.1-3 for 38% validity and 22.1 for 93% validity) of these expectations of the value in the range indicated that some subjects *consistently* used low expectations (low end of range), some rational expectations (50%), and others high expectations (high end). Since markets are affected by behavior on the margin, this risk preference affects prices.

In the next sections, the analysis will cover the price dynamics of clearing prices from all sessions by institution.

5.1.2 Prices under DA1

Prices for dual values

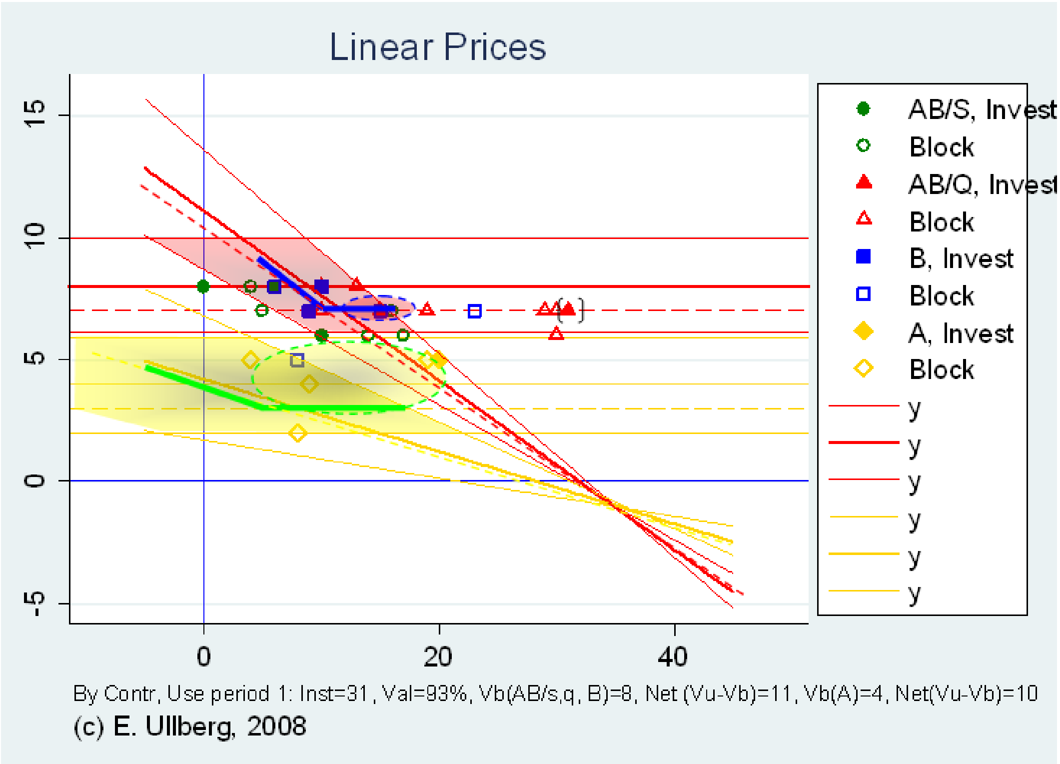

Fig. 11. Sessions 6, 7, and 9. Actual prices for the different markets (AB/s,q, A, B) with Max. fixed, royalty price ranges (solid l.) and E(fixed, royalty) prices (dashed l.). Min. fixed, royalty prices not indicated for clarity.

The first experiments with qualified subjects, sessions 6, 7 and 8, were for high validity patents exchanged using the DA1 institution and are charted in Fig. 11. 8 trained subjects participated in each of these experiments: 1 inventor, 1 trader and 6 users roles, 3 in "industry" with "product mix" of A or B with rotation between roles.

In Fig. 11, the linear clearing prices for the contracts traded are plotted with the fixed price on the y-axis and the royalty price (expressed as a percentage) on the x-axes. The linear prices for each type of market (AB/standard, AB/quality, A and B) are indicated with a different symbol. The symbols that are filled indicate that the contract was used to *invest* (in period 1) to create a new product (A or B). If they are hollow, the contract was used to *block* (in period 1) to earn a profit from an existing product (A or B). To show profitable bids solid lines are plotted for the expected profits from blocking and investing based on the upper, middle and lower end of the respective value ranges (Max. Fix(t) and Max. Royalty(t))[25]. Profitable asks (Min. Fix(t) and Min. Royalty(t)) are calculated in the same way, but for clarity, these values are not drawn in all figures. The lines form a polygon box (shaded) within which prices can be profitable given the uniform random realizations of the ranges. The bold line indicates maximum prices at which contracts are profitable on average. To show expected prices, two

[25] Realizing the blocking values will result in horisontal lines (no royalty is paid when blocking). Profits for a user = Vblock(t). t=period 1,…,P. Profits from investment values will result in sloping lines (fixed always has to be paid). The investment value, given as a range of increase in revenues from investing, is converted in the graph to a corresponding maximum royalty as a percentage, minus the fixed price paid, minus cost of goods sold (COGS) and minus an investment each period, related to the new production (and marketing) costs. Profit = Vinvest(t) (1-COGS-royalty(t)) – fix(t) – Investment per period. Solving Profit invest for royalty(t) gives E(royalty(t)).

dashed lines are used to indicate E(Fix(t)) and E(Royalty(t)|Fix(t)). Where they cross represents the expected clearing price according to the proposed theory of prices. Due to high volatility in prices, mostly in the royalty dimension (this changed some over time in the experiment as subjects became more experienced but consistently remained higher than the fix.) and for clarity, an average price is calculated and drawn as a circle/ellipse, +/- 1 standard deviation from the average.

The average fixed price[26] for the AB/s, AB/q, and B contracts in experiment 6-8 is 7.0 (28 obs.) and prices are narrowly spread around the E(Fix(t)), the midpoint of the second-highest value range (=7). All prices are lower or equal to the midpoint of the highest blocking value range (=8) and higher than the lower end of the highest blocking value range (=6). These results indicate initial support for the proposed theory where the fixed should be equal to the midpoint of the second-highest blocking value. The average royalty price is 13.9% which is higher than what can be explained by the investment value (=11%), but on average just inside the high end of the investment range.

The prices show an interesting dynamic: Most fixed prices are at the second-highest blocking value. The lowest value are at the highest agent's low end, indicating a clear limit of minimum price. The maximum price is at the mid-point of the highest agent. The behavior suggests a dynamic bidding process between the two highest bidders and, on average an approximate risk-neutral bidding behavior and a clear understanding of minimum profits.

The contracts that are blocked (in period 1) have a higher royalty on average than contracts that are invested in, but there is no apparent difference in the fixed price. Comments like "When I see royalty prices go higher than what is profitable, I know that the buyer intends to block" indicate that participants are aware of this bidding behavior. However, prices are not at 50% (the maximum), indicating a restraining behavior in prices when buying to block. Tradability of a contract (prices are profitable for both investing and blocking) may have been one such concern. Being able to price this future value aimed at managing one's own risk in profits from future periods (period 2 and 3) would indicate a pricing strategy prompted by the uncertainty in induced values. Subject comments along the lines "We want to be able to resell the contracts. It's too risky without. One can get stuck with a contract." suggest that the tradability value was in fact part of the pricing strategy, at least among some. Such behavior would be consistent with risk management behavior in liquid markets. Another explanation for restrained royalty prices may be that in the DA1 mechanism buyers can increase the bid *if necessary* to win the contract, but may not always do that initially to keep their intentions private. Interest in re-trading was high during many experiments. Contracts were more or less consistently put up for resale, though these efforts only occasionally resulted in any trades (initial allocation was efficient), and in spite of the fact that this was a time-consuming task, reducing the number of earning rounds in the experiment and reducing earnings for all participants (a behavior consistent with short term profit-seeking). This prompted the introduction of a small transaction cost, which resulted in more experimental time for primary market trade. Only when unusually "low" or "high" prices were agreed upon (inefficient allocation) did a resell then take place. Positive and negative prices were observed.

But even when investing, the royalty price appears to be slightly "high." This may have an explanation in the design. Since the fixed (and royalty) prices could only be given as whole numbers, a marginally higher royalty (which has a smaller impact on cost than a higher fixed

[26] In these initial experiments, there was no clear difference between the AB standard, quality, and B contracts. They had typically the same induced value but the strategic use, split for quality, no-split for standard, and demandside competition differed, A and B industry users, or A or B industry users for split contracts, factors that could affect prices. However, a small difference in price, consistent with competitive bidding, is reported at the end of this section for the contracts that were split.

price) might have been used to win the contract, keeping the fixed at the second-highest value. This potential experimental design effect may be reduced in future experiments by using bigger numbers and/or decimal bids.

The average A contract price is 4.2 (only 5 obs.), which is slightly higher than proposed theory and is close to the midpoint of the highest value range (=4). The average royalty price of 12.0 is also higher than the NPV hypotheses (=10) and just outside the rational expectations "box." Although considerably fewer data points were recorded, it appears that similar pricing preferences can be seen in the prices for A and B contract. The prices indicate a clear separation in prices with respect to the AB/B and A contract values.

About 30% of the contracts are invested in (70% blocked) and about 80% of the quality contracts (that can be split) are split, leading to an average of 50% of all contracts are split, and thus generate dynamic gains.

Tentative conclusions for DA1 are: the results indicate support for the proposed informal theory for investment use. When the usage is blocking, buyers tend to express their WTP in the fixed (which they have to pay) at a level close to the blocking value but overpricing the royalty (which they don't have to pay in that use). When the usage is investing, buyers tend to express their WTP at royalty levels close to the investment values that can still make a profit, given their WTP for the fix, which again appears to be close to the blocking value. The blocking and investment values thus appear to be *independently* expressed (no linear trend in fixed prices) in the fixed and the royalty dimension to the competitive price level (second-highest values), making the institution incentive compatible (static efficiency). This also suggests that even if an individual buyer intends to invest, that buyer still has to pay the competitive blocking value.

The number of split contracts indicates the propensity for the traders to make a profit by first outbidding all industry users and then creating two new "split" contracts with limited rights to each industry A and B, and subsequently sell them one after the other at competitive prices to a user in each industry. The economic value of the initial contract (technology) is thereby "multiplied." The dual values of the A+B markets are potentially realized as a result of trading, increasing the social gains in the system (can maybe be characterized as Pareto gains[27]).

Seeing this market as an integrated market (as in the international trade literature), gains would be generated by the mechanism of impersonal exchange proportional to the propensity to increase the usage of the patented technology to generate market access.

[27] Pareto gains is a static concept and for small changes. However, here it is a dynamic context, but as we look at the total system gains, everybody is better off when splitting. This is due to the fact that more market access is created in the process. The incentives are aligned between risk-averse inventor-trader bidding and then trader-innovator bidding (which is not the case between risk-averse inventor-innovator bidding who favors opposite positions on fixed fee and royalty).

Prices for random variation of contract values – "robustness" test

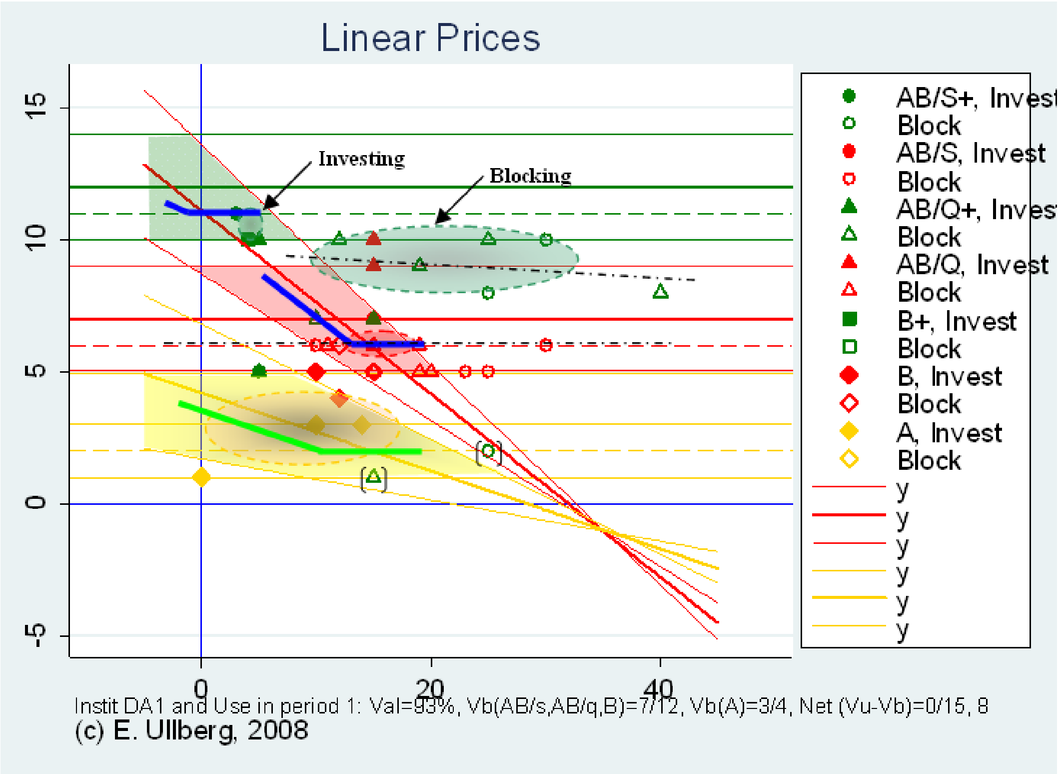

Fig. 13. Sessions 18.2 and 19.1. Robustness test of DA1.

This separation of the A and B contracts indicates some robustness of the institution to price contracts according to value. However, since the same trained people returned to the next sessions, common expectations quickly formed *across* sessions. This resulted in a long "hysteresis" effect when the values were changed, lasting most of a session. The "solution" chosen was an extension of the experiment and to use two alternating values for the AB/B contracts where the blocking value was randomly altered between high/low values. This extension, more importantly, provided for a *robustness test* of the institutions at the same time. The question now became whether this institution was also able to "distinguish" in prices, based on fundamental values, between contracts of the same type (AB/B) but with different values (a "two-commodity" market)[28]. The results are chartered in Figure 13. In sessions 18.2 and 19.1, using Values5, a high B value (=12) was therefore randomly introduced in the previous value set (B=7, A=3/4). I find a clear separation between both the high and the low B contract values and A contract values, indicating robustness. The prices generated for the contracts when investing also appear to give additional support to the price hypotheses. However, the prices of the high AB/B-values when blocking appear to follow another pattern. There is a much higher propensity for blocking use, as blocking becomes more profitable (although the same profits could be achieved by investing). The royalty prices are considerably higher for the blocking use than the investing values (as in previous sessions). This decision of a "safe," but potentially lower, profit appears to be consistent with risk-averse behavior. If one uses the prices from participants with much experience, > 5 sessions, the "investing" prices are within the "rational box". The blocking values are however still "undervalued" but close to the lower blocking value range. In a similar way as the previous experiments, A-contracts on average seem to be slightly overvalued.

[28] This expansion was discussed to some detail with Prof. S. Rassenti, particularly the "robustness" test.

By accepting a high royalty, only high value "blocking" buyers are able to participate, reducing the competition and possibly colluding with the remaining high blocking value buyers, reducing the fixed fee further. The tradability option in period 2 and 3 appears not to be sufficient to restrain overbidding in the royalty price when an "easy" profit can come from blocking. Yet another possible factor for these prices is that at least some participants "average" the values of the contracts, i.e., form common expectations for both high and low value contracts. This "rule of thumb" pricing was observed in comments by *some* participants, i.e., "I always start at (10,15%) when bidding," whereas others appeared to try to get the "fundamental value" prices. There appear to be competing bidding strategies at play simultaneously. Also, only blocking is profitable except for very low royalties and some lower value "blocker" may bid up the royalty and thus force high value users to bid for blocking use (royalties are overlapping).

I conclude that similar results are found in these experiments as in the first. It seems that the hypothesis of the fixed price is strengthened if the use is investing (no obvious linear trend in prices). The uncertainty in the values is not enough to restrain agents from "destroying" the tradability value by bidding a high royalty, at least not when the values are given for all three periods at once. If given only one period at time, perhaps that would change the expectations of future earnings and this behavior (which may be closer to some naturally occurring environments). About 25% of the contracts are used for investment and about 28% of all contracts and 40% of quality contracts are split and generate dynamic gains.

6.1.2 Prices under DA2

Prices for dual values

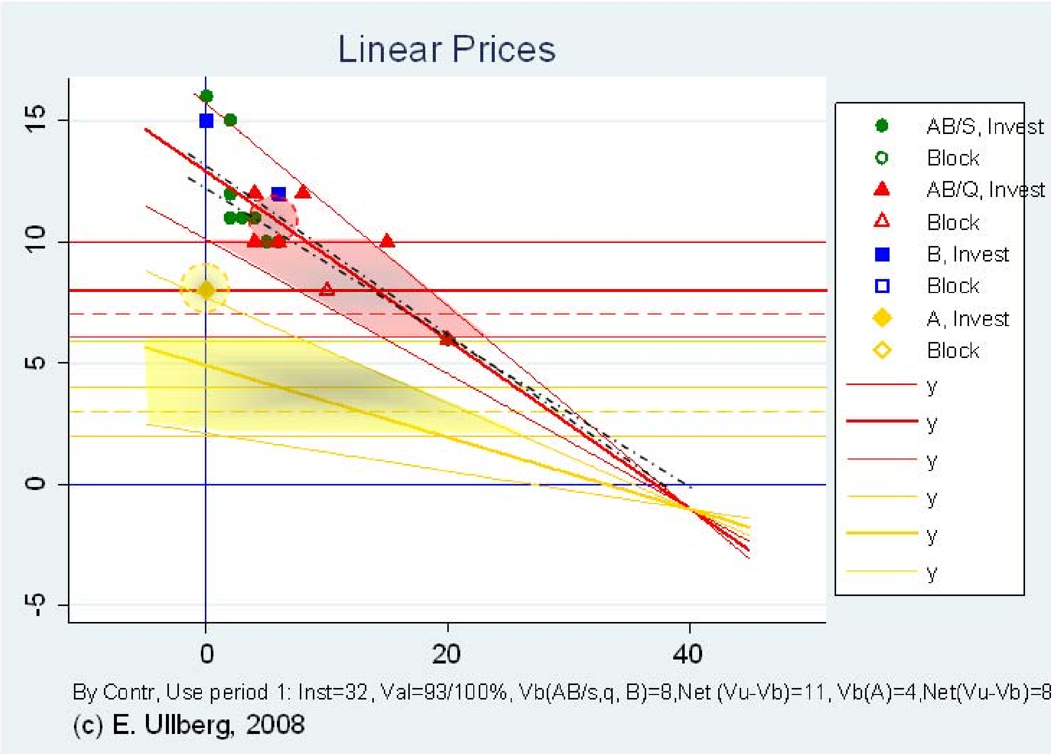

Figure 14. Sessions 10, 11.1. Institution DA-2. The royalty prices lay close to the investment values, given what is paid in fixed. The upper dash-dot line includes all prices and the lower only non-split contract prices.

Once we had learned something about prices using DA1, the second institution was tested to compare the prices using a reservation value on the fixed component, reducing the bidding space to the royalty dimension but having the same public information. In experiments 10 and

11.1, Values2 were used with institution DA2 and chartered in Figure 14. The contracts are significantly higher in the fixed price, consistent with risk-averse behavior by the sellers. However, the royalty prices appear to be fully compensated to a royalty that makes the contract profitable for investing. All contracts above the middle blocking value are used for investing, consistent with the fact that blocking is not enough to make a profit on average. The higher fixed fee changes the *incentives* for the buyers, investing more in the contracts, generating royalty and fixed income for the inventors. In real world contracts, the inventors often try to negotiate a fixed payment (commonly an up-front lump sum, milestone payment or some minimum payment scheme) to "incentivize" buyers to make efforts to invest in the contract, overcoming the moral hazard problems[29]. In the experiment, the proposed interpretation is that the buyers are willing to pay the blocking *value* in the fixed fee and trade some of the investment profits to get the contract, but only if they have to. In contrast to previous sessions, the prices show a clear linear trend, making the fixed and royalty components dependent. The slope of the trend is almost identical to the highest value bidder (not the second-highest), indicating that the buyers are overpaying somewhat with respect to predictions. However, these prices include split contracts, where the price should be higher. Taking out these contracts may put the regression closer to the second-highest value. Two other observations can be made: 1) the propensity to invest was higher than DA1 with about 60%, but slightly less split contracts traded, about 20%; and 2) too high fixed reservation values also lead to several "no trades," which are a loss for the seller (these contracts are not shown in graph).

Prices for random variation of values – "robustness" test

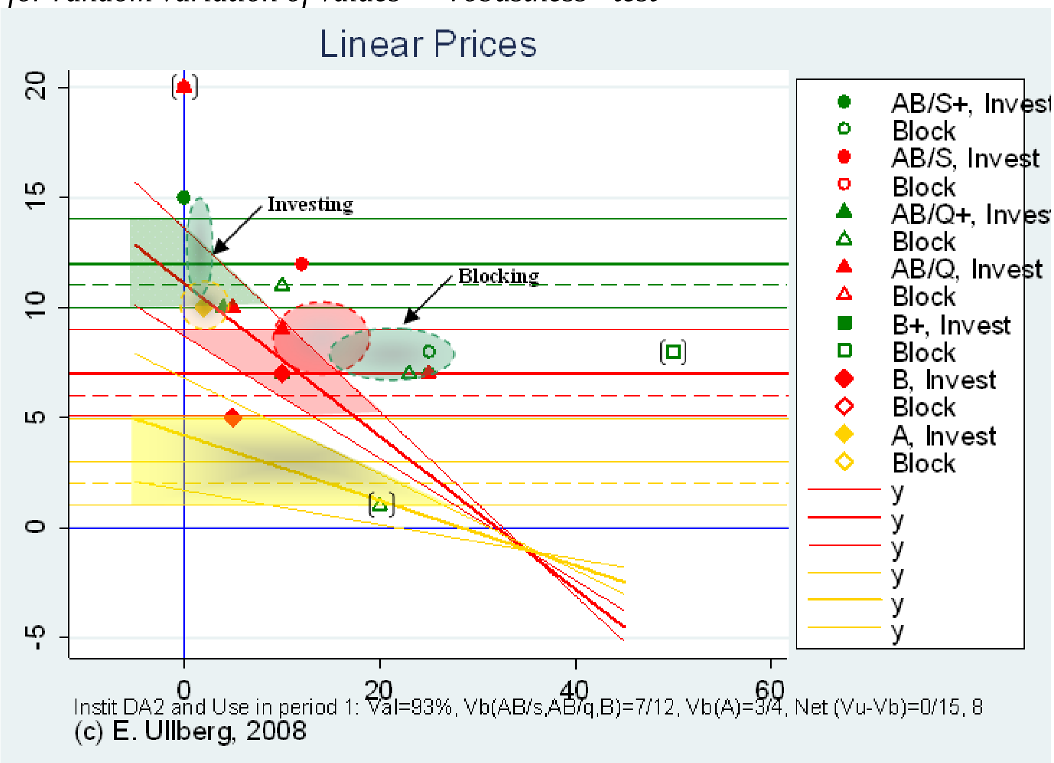

Fig. 15. Session 18.1. Robustness test of DA2.

As was done using DA1, a session with random AB/B contract values were also run for DA2 to study robustness of this institution. The results from session 18.1 are chartered in

[29] Interview with one of Sweden's most successful inventors, Karl Derman, confirmed that this incentive was critical and without the fixed payment, priority may be given to other projects in the decision making process.

Figure 15. The considerably higher fixed prices are consistent with experiment 10, 11.1, but the data clearly appears more noisy and with less apparent separation between the high and low B-contracts. Many prices are also profitable. In part, this may be explained by experience. If outliers are excluded on the basis of lack of experience and the investing and blocking values are distinguished from each other, there seems to be a separation of prices between high and low value B-contracts. The average price for the high value B-contract is within the "rational box" for the investing use. The blocking use is lower than the minimum value, just as for DA1. The same reasons may apply here as for DA1. Again, only 1 A-contract was traded and the price is clearly higher than the blocking value and more in line with the B contracts. The data set is, however, small (7 obs./value).

The conclusion from these two experiments seems to reinforce the tendency under DA2 for higher fixed prices. The royalty prices are then (linearly) compensated to create a profitable contract for investment. The fixed price hypothesis appears not to hold in this one-dimensional bidding. An auxiliary hypotheses then becomes: When a reservation value can be set on the fixed fee, the prices follow a linear pattern, compensating for a fixed fee > blocking value by reducing the royalty. The gains from trade as expressed by split contracts are low in DA2.

6.1.3 Prices under PO

Prices for random variation of values – "robustness" test

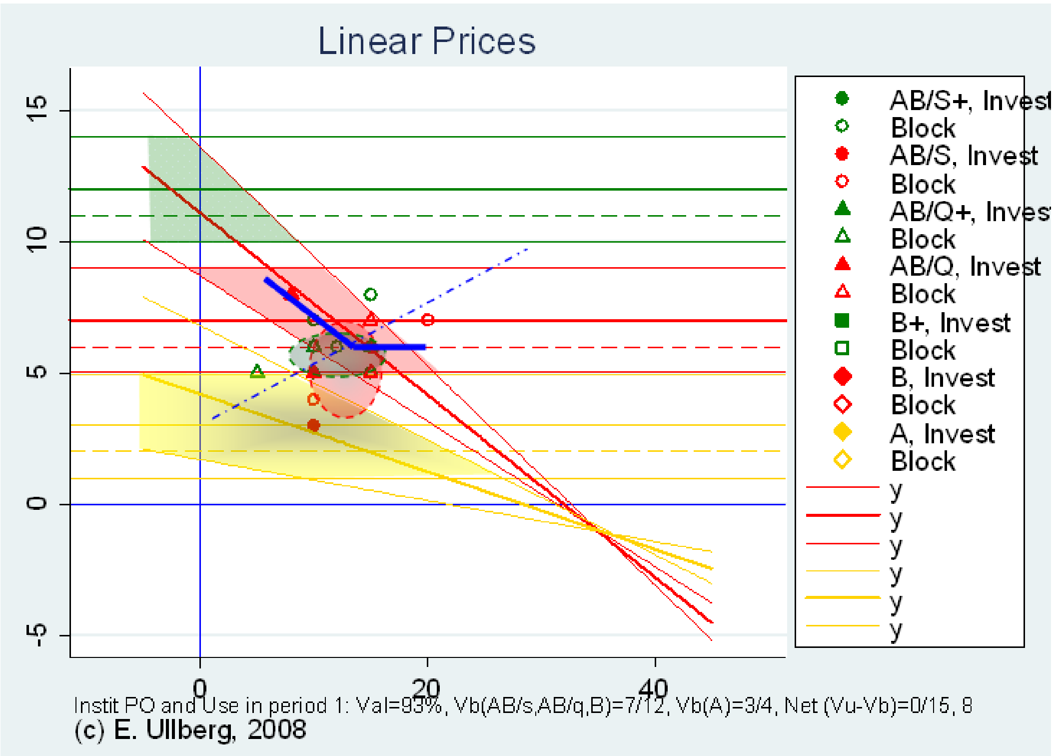

Fig. 16. Session 19.2. Robustness test of PO.

Finally, the PO institution was tested using random AB/B contract values and is chartered in Figure 16 (session 19.2). The PO institution appears to be considerably less able to distinguish the differences between the high and low values. In fact, in this session, common expectations appear to have formed for both contract values at the lowest value level. This may alternatively be explained by the riskiness of exploring high values, since there is limited information on WTP (only accept/reject of sellers WTA). Prices appear to be slightly lower than what are predicted by the hypotheses, but are expressed in both the fixed fee and the royalty near the competitive price. Also none of the contracts were split, which means that there were no dynamic gains from trade. An interesting incentive appears to be that prices are discovered in a way in which both the fixed and royalty are changed, showing a weak positive linear trend in the prices (the slope of a regression of the prices is positive (not statistically significant result)). This line intersects near the rational expectations price.

A tentative conclusion seems to be that prices are lower than in the other institutions, which shifts profit from the sellers to the buyers. Since this institution is the one closest to today's *personal* exchange, the result suggests that high value technology may be undervalued due to lack of competitive demand-side bidding. The supply side is unable to fully discover the WTP of the demand side without demand-side bidding. It is interesting to note that this institution—the most similar to today's trade— results in 70% blocking (only 30% of the contracts where used to invest), which is a common critique from inventors when they sell their patents to innovators.

6.1.4 Prices for split contracts under DA1

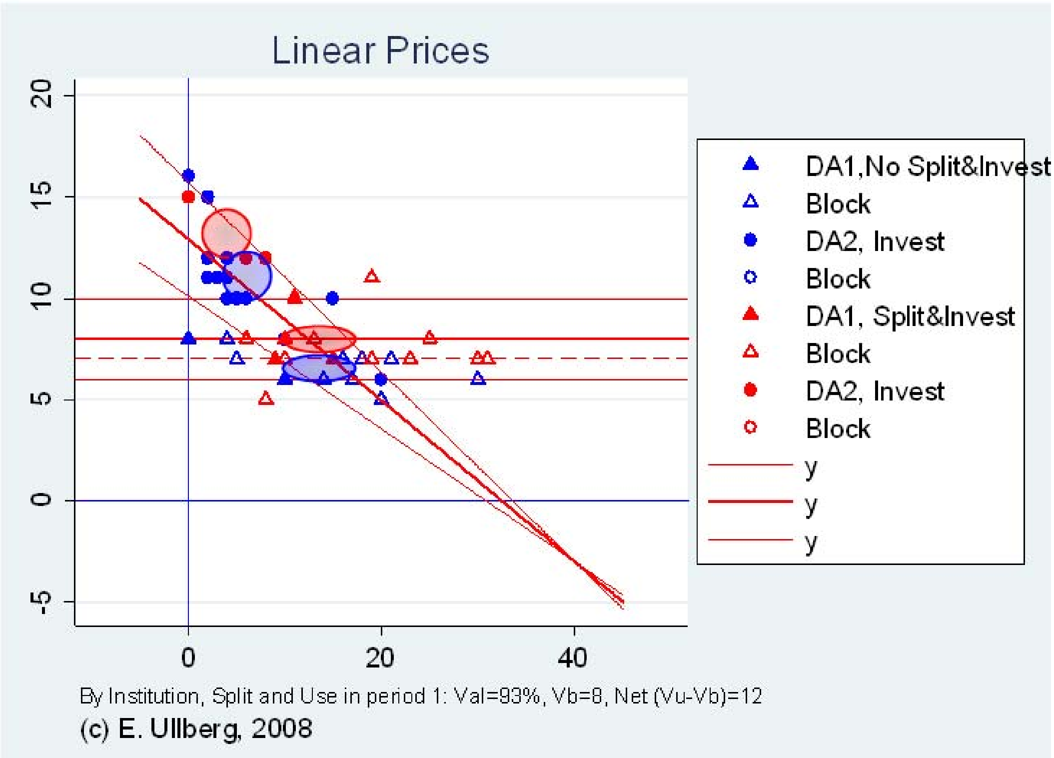

Fig. 17. Sessions DA1: 6, 7, 8 and DA2: 10, 11.1. Split prices appear to follow the same value logic, where traders (role2) on average bid close to the highest user's (role3) values.

A last look at the prices for high validity contracts , now differentiating between contracts that are split and not split, is chartered in Fig. 17 (sessions DA1:6, 7, 8 and DA2:10, 11.1). Split contracts give slightly higher prices in fixed than non-split contracts for DA1 and higher fixed with lower royalty for DA2, indicating that traders outbid role 3 using the fixed component. Outbidding the highest user's values then puts the competitive price at the highest value (the upper fixed line), which can be seen in the figure. The trader turned out to be a rather difficult role for most participants. The fixed price is close to 8 (7.8) for the split contract, the highest role3 value, whereas it is close to 7 (6.8) for non-split contracts, the second-highest role3 value. This indicates that the inventors benefit in the fixed price from the increased value created by the trader splitting the contract. The dynamic profit incentives are actually aligned between the specialized agents to maximize the use of the technology: inventors with a tendency to be risk-averse (as seen in the DA2 where a higher fixed free is a behavior consistent with risk aversion) prefer fixed, but users prefer royalty for the same reason (they don't want to expose themselves to a high fixed, especially not if investing). The trader can take on a higher fixed fee by potentially "multiplying" the fixed fee from the two split contracts. The trader can then accept a lower fixed free for a higher royalty from the users, something that is in the interest of the users. This mechanism thus provides the system with higher dynamic gains based on trade and risk-sharing in a larger consumer market. The role of a trader therefore appears critical in increasing dynamic gains from trade in patents.

6.1.5 Price comparisons between institutions

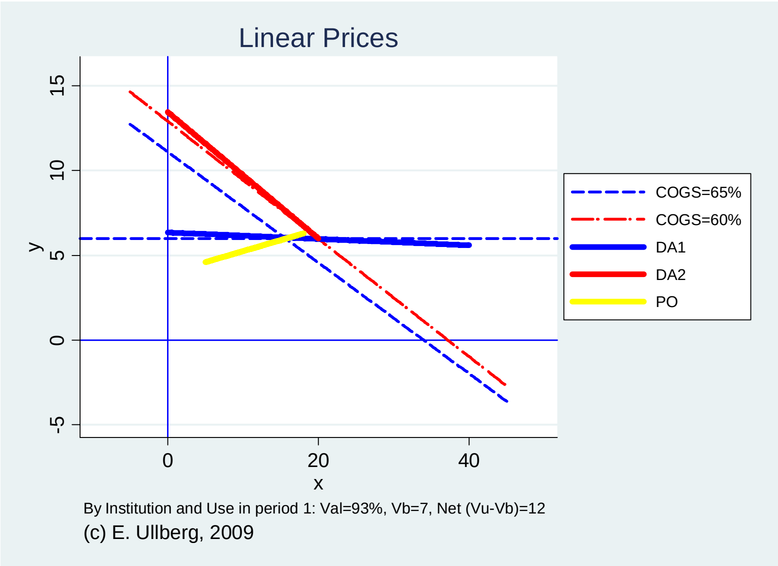

Fig. 18. Sessions DA1:6, 7, 8, DA2: 10, 11.1, PO: 19.2. Pricing dynamics.

I have now examined results from the three institutions with respect to prices and gains. Is there a consistent pattern of prices that can be seen? A comparison between the three institutions for the AB/B contract is charted in Fig. 18. The incentives created by the different rules give very different dynamic price patterns. DA1, the only institution with two-dimensional bidding, appears to price both the fixed fee and royalty, in support of the proposed theory (especially for contracts invested in). DA1 also has the highest number of split contracts, i.e., the highest dynamic gains with respect to the use of technology (for invest and block). DA2, with one-dimensional negotiation, has clear incentives to generate high fixed values, but at the cost of lower royalty and fewer split contracts. This means that the sellers have to pay for the lower risk they want (by asking a high fixed fee increasing risk transfer) in reduced potential returns from production (lower risk sharing). (Sellers "can't have the cake and eat it"). This is particularly unfortunate since almost all contracts then have to be invested in, a situation that would *favor* a high royalty agreement for the sellers. The buyers also appear to overpay in royalty. PO, with no fixed fee or royalty bid information from the buyers, has the lowest volatility in prices ("set" by seller), but also fails to price high value contracts according to fundamentals. It is a rather costly venture for the seller to discover prices by failing to sell contracts. This appears to push prices down to a common expectation across contracts at the lower contract value level.

The tentative conclusion from the high validity experiments gives experimental support for the proposition of division of the fixed and the royalty with respect to blocking and investment value: one needs two-dimensional institutions to express the two-dimensional value independently in the two-dimensional linear contract. These tentative conclusions may be fruitful for further investigation to inform economic theory on prices on patents and trade theory on dynamic gains from trade in patents. How such models can be created is a subject in its own right and not treated here.

6.2 Experiments with low validity

6.2.1 Prices for DA1

Prices for random variation of values – "robustness" test

The next group of experiments *repeated* the study of prices for the different institutions but with "low" validity at 38%, which introduces substantial uncertainty in the contract value, especially for investing use. The environment with random high/low AB/B values, the "robustness test," was used.

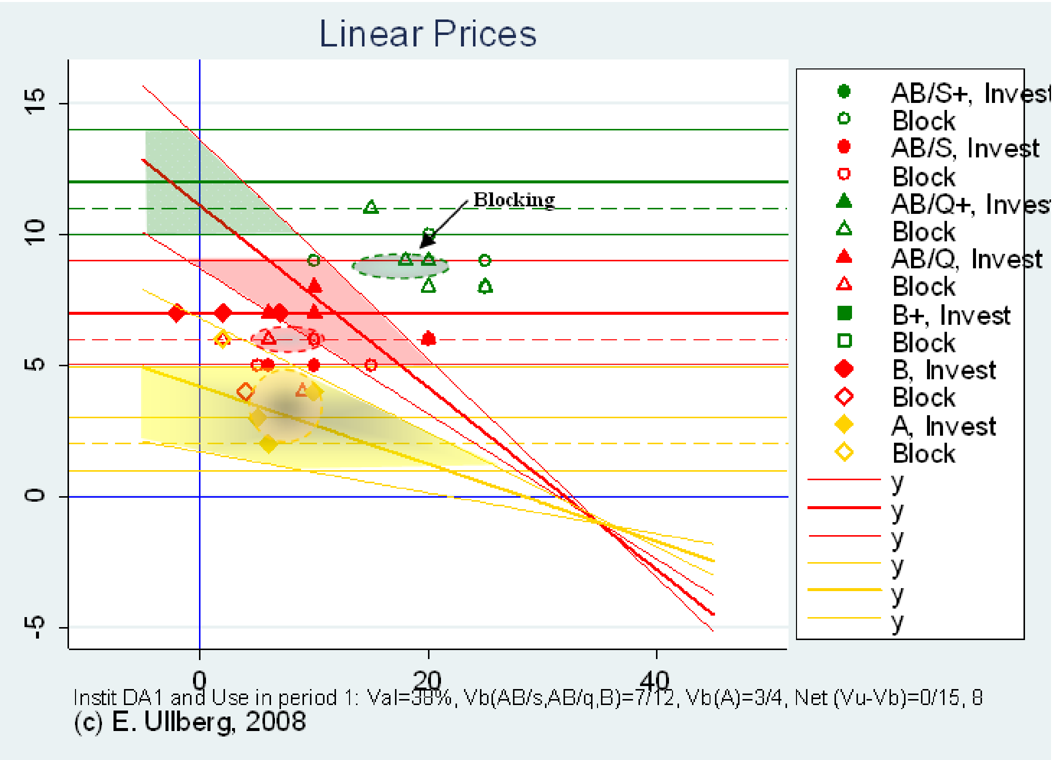

Fig. 19. Session 21.1. Prices for DA1 under low validity

The results paint a picture similar to that of high validity, particularly with regard to fixed prices. The prices are separated clearly with the lower B-contract around the blocking value and the royalty below the lower end of the value range. Also, almost all contracts of this type were invested in. The higher B-contracts are lower than the lower end of the blocking value and priced higher than the highest royalty value. All contracts of this type were used to block.

The A-contracts are priced higher than the blocking value but about the middle of the investment value.

The profits from investment are calculated in an industrial approach, with three production batches during one period, generating inventory to sell. If the contract is invalidated, the remaining inventory is lost, generating a loss proportional to up to 1/3 of the revenues for that period (similar to receiving a court "injunction"). It therefore appears that this risk of loss of inventory and profit is reflected in lower royalties, i.e., less risk-sharing, as buyers try to compensate for a potential loss. The patent system can therefore be seen as a "risk management institution" for the trading partners, whose actions are important for the risk-*sharing* in the contracts.

A tentative conclusion is that the hypothesis on the pricing of the fixed is further supported. However, for the high blocking values and low investment values, subjects appear not to discover the most profitable use, but again "settle" for a safer blocking strategy. The lower validity appears to lower the royalty price, consistent with compensating for this risk of loss from production. The prices of the contract appear again to be related to the usage. The propensity to invest is around 20 %, which is considerably lower than for high validity. The propensity to split contracts is 25%, which is comparable to high validity.

6.2.2 Prices for DA2

Prices for random variation of values – "robustness" test

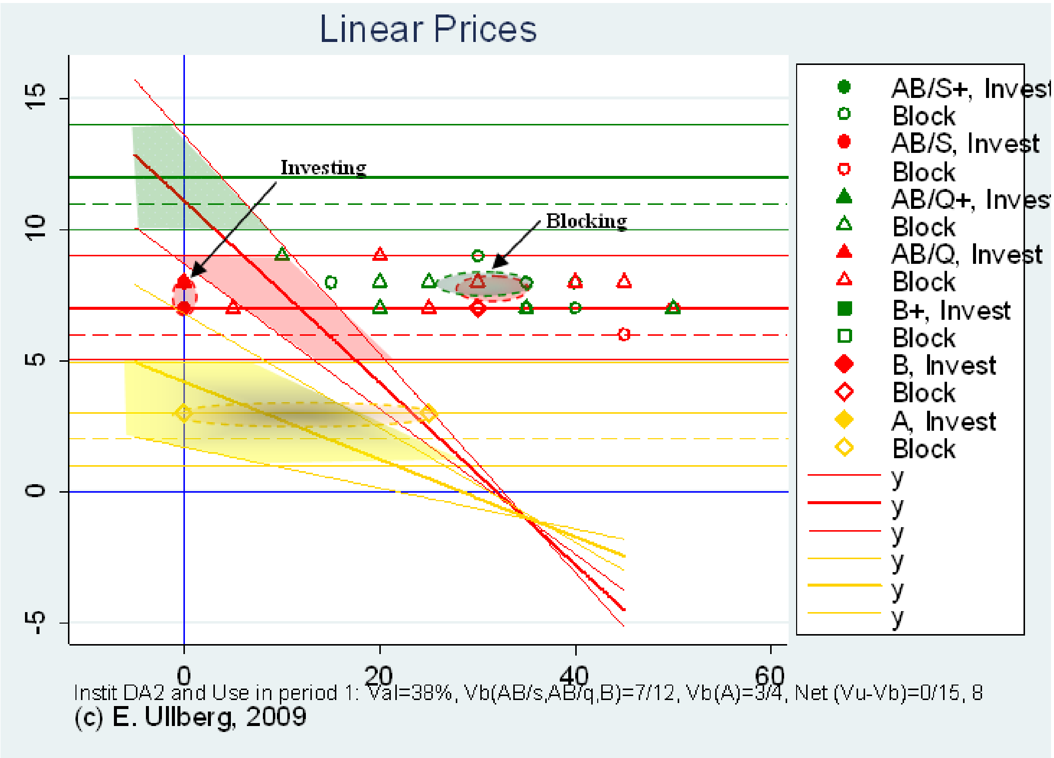

Fig. 20. Session 22.3. Prices for DA2 under low validity.

The DA-2 institution prices the values quite differently under low validity. Almost all contracts are used to block. The B/B+ contract prices are indistinguishable and common expectations appear to have formed near the higher end of the lower B contract value. This can be explained by the fact that the increased risk in investing makes buyers unwilling to trade off a high fixed for a royalty, "forcing" users to block. In fact, the only time users invest is at a royalty rate of 0, i.e., low risk with respect to royalty payments. It may also be explained by the sellers not asking high fixed prices (they did not learn how to trade in this environment), giving no incentive to trade off between fixed fee and royalty. An additional study of non-traded contracts may reveal if this is the case or if buyers simply do not accept a high fixed fee. The (only 2) A-contracts are, however, priced closer to fundamental value.

The two contracts traded for investment clearly have a lower royalty than under high validity (the only contracts recorded with 0% royalty). This result indicates that the adjustment in the price from variations in validity is done in the *royalty*. This is probably motivated by the risk of losing the investment value in the low validity treatments. This is thus a result consistent with DA1. This session was run last (high experienced participants) and in the middle of experiment 2 (with the same institution). These results may therefore only be indicative and a re-run could possibly give a different result. Here the stable end-state is clearly blocking. The propensity to invest is around 10 %, which is considerably lower than for high validity. The propensity to split contracts is around 20%, which is comparable to high validity.

6.2.3 Prices for PO

Prices for random variation of values – "robustness" test

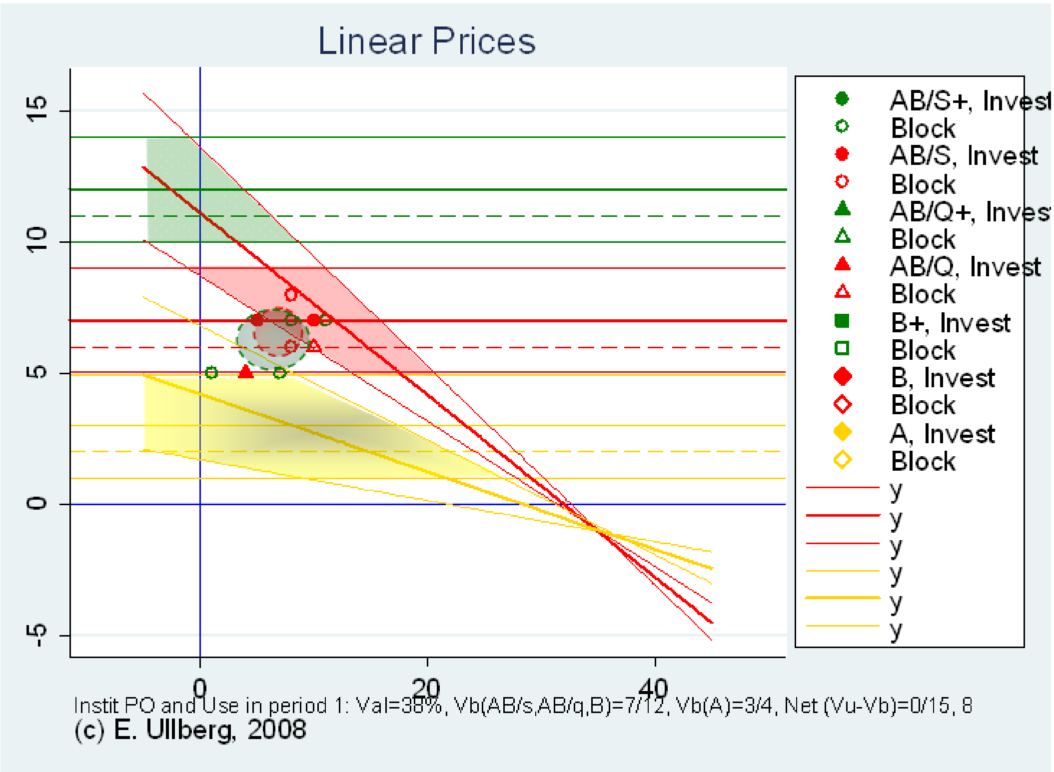

Figure 21. Session 22.2. Prices for PO under low validity.

The prices for PO are not possible to distinguish between high and low AB/B contract values, a result similar to high validity contracts. The difference appears to be in a lower royalty, like the other institutions. The propensity to invest is around 33 %, which is considerably lower than for high validity. The propensity to split contracts is around 8%, which is also low compared to high validity.

When comparing the average prices between the three institutions for the lower validity, there is a consistent trend toward lower royalty prices (which one would expect). The royalty prices are about 15-30% lower with about 60% lower validity (93% → 38%). A tentative conclusion is that institutions seem to have the same price patterns (same incentives) and the change in the legal environment reduces the WTP, a royalty apparently to compensate for the risk of loss of production (inventory). This compensation takes its expression in the royalty only, not the fixed fee.

6.2.4 Prices for split contracts

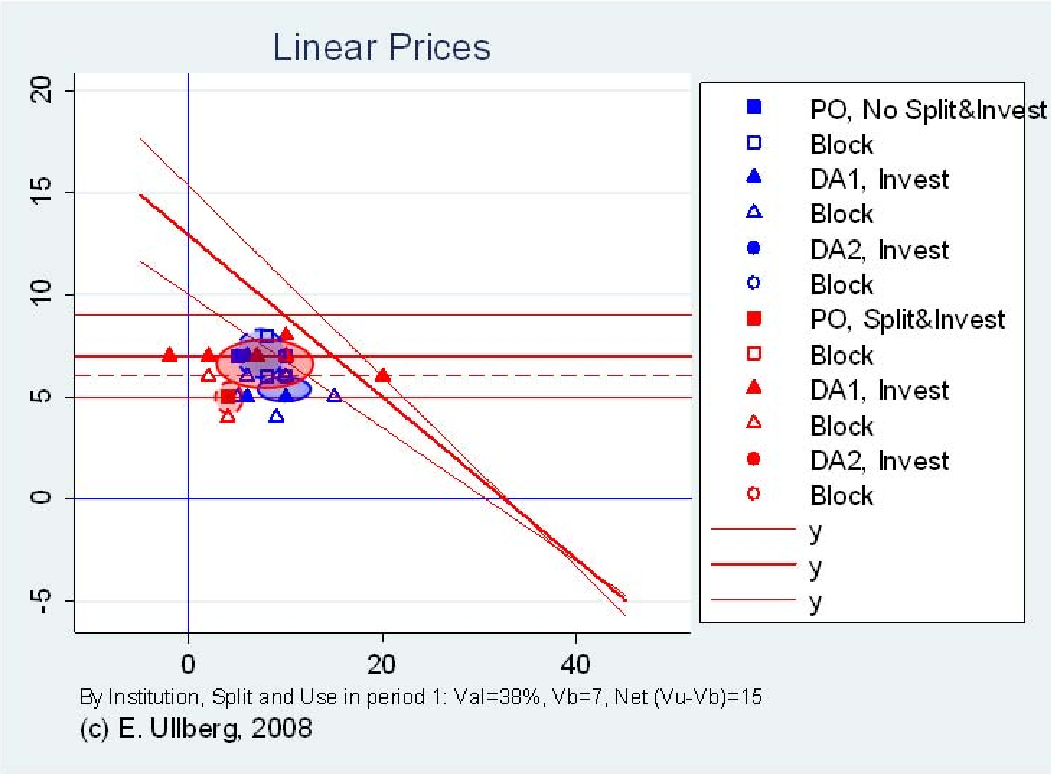

Figure 22. Session 22.1-2. Split prices under low validity.

The prices paid for the split contracts for the three institutions under validity 38% are chartered in Figure 14. The split contract prices are slightly higher, as in the case of 93%, here shown for DA1. The incentives for trade appear to be unchanged with respect to validity.

6.2.5 Comparison between institutions

Comparing the price dynamics for the institution under low validity indicates a more common behavior among the institutions than under high validity. See Fig. 23. The fixed prices are generally independent of the royalty. This can be explained by the higher propensity for blocking (possibly due to uncertain value to invest); therefore, it is basically the blocking value that is priced. A noted, the DA2 session was run after the others and may result in a more pronounced trend if re-run. The indication is that with low validity, mostly the blocking value is priced. This is clearly an indication of a different end-state of the system than for high validity patents, with possible implications for patent policy.

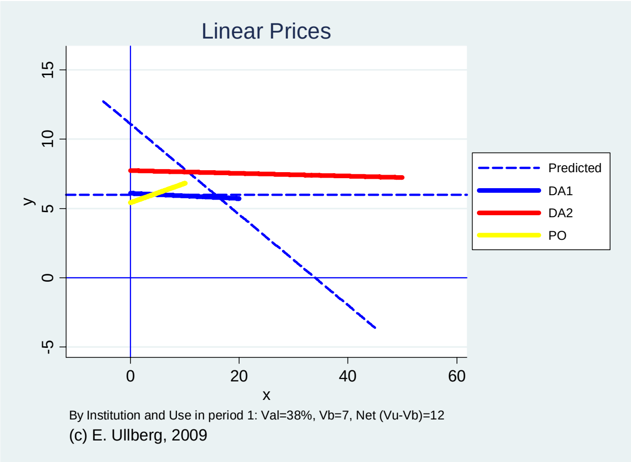

Fig. 23. Sessions DA1:21.1, DA2: 21.3, PO: 21.2. Pricing dynamics for low validity.

6.3 Secondary market reallocation

The secondary market was used in periods 2 and 3 to reallocate contracts, for a fixed price, bought in the primary market, for a linear price (fixed fee plus royalty). Only a low frequency of actual trades was observed, indicating that the initial allocation was perceived to be efficient. 10% of primary market transactions (in period 1) resulted in a reallocation (in period 2 or 3). Of these, only 6% had a price different from 0, i.e., the transfer was accompanied with a price to be paid. Only 2% were transacted under low validity.

Solving the allocation problem in the primary market and not the secondary appears to be an important factor in understanding the dynamics of the system, since the time value of a patent is critical (for competitive market access in the technology market) and limited. A typical "trial period" of a technology is 1-3 years and getting it wrong the first time may cut the economic life in half or completely take it away.[30] A well-functioning primary market therefore adds to the time value of the patent, a dynamic effect of the system.

6.4 Homework

For the homework assignment at the end of the experiments, participants were asked to write instructions for future participants in the experiment and elaborate on their *bidding strategies* in the different treatments. This was a paid exercise[31]. The findings appear to be consistent with what they did in the sessions, i.e., they had implemented the strategies they described in the homework document. The findings are reported as statements. Main factors contributing to profitable performance were noted as: the competition (how strategic the other participants were in their bidding) and the different treatment conditions (institution, validity). Comments like "It is important to adapt your strategy to the different conditions in order to maximize profits," indicated that the incentives were quite different under the different institutions. Some gave elaborate programs on what to do given the treatment.

Some general comments given by most participants, sometimes several times, was: "Don't be greedy," "Slow and steady will get you ready," and "BE PATIENT," possibly indicating experience build-up over time. When bidding, one participant expressed the maximum price

[30] Average maintenace time of a patent is about 7 years, varying from 0 (chip industry) to 30 years (pharma with patent extention time). For most technologies, initial efficient allocation would therefore be critical, making the institutional design a critical factor affecting the price.

[31] This idea was suggested by Prof. S. Rassenti.

to bid as: “As a rule of thumb, pick 1 value less than the middle value of the blocking range as your highest bidding price in order to increase the chances of making a profit of more than 50%.” This corresponds to the smallest possible profit to make greater than 0 on average. It also corresponds to the mid-point value of the competing buyer just below, thus putting the buyer at risk of losing the contract to the second-highest value bidder.

In this section, I have given an overview of the experimental results, comparing linear prices obtained in the dynamic system under three different mechanisms and two levels of patent validity, with the dual values of a patent. I have shown that there are indications that the dual values block and invest appear to be separated with respect to (market access) risk in such a way that they can be expressed in the linear contract dimensions fixed fee and royalty. The pricing behavior, contract usage, and dynamic trade gains also vary among the institutions.

7. Linear Prices, System Gains and potential Capital Allocation: Hypotheses and empirical results

In formulating some hypotheses on the linear prices, I will distinguish between the predicted prices based on the proposed informal theory (nomothetic experiment) and the heuristic study of the messages and information, both under the different institutional arrangements and legal validity. The first approach studies under which particular institutional and legal settings convergence to the predicted outcomes is more likely. The second approach aims at discovering differences in price outcomes between the different institutions and legal environments. Capital allocation is a simple calculation based on the dynamic gains as an indication of systemic risk between treatments.

7.1 Linear prices compared with proposed theory (static analysis)

I begin with the question of predicted static “equilibrium” prices versus observed prices. The theoretical proposition predicts that the willingness to pay a fixed price is equal to the second-highest blocking value plus epsilon and the willingness to pay a royalty price is equal to the second-highest investment value, net the fixed price already paid, plus epsilon[32]. The question of how accurate the predicted prices are with respect to the observed prices is examined using a t-test of the difference between the predicted values and the observed values

$$(1a)\ fix - fix^{*} = 0 + u,\ fix^{*} = Vb_{-1}$$
$$(1b) royalty - royalty^{*} = 0 + u, royalty^{*} = \left[\left(1 - COGS\right) - \left(Vb_{-1} + investment\right)/ Vi_{-1}\right]$$

where *fixed* and *royalty* (expressed in percentage) are the clearing prices and predictions (* superscript), Vb_{-1} is the midpoint of the second-highest blocking value range, Vi_{-1} the midpoint second-highest investment value range, *COGS* are cost of goods sold (1-*COGS* is then the “gross margin”), *investment* is the periodic investment if investing in the contract (development, marketing), and *u* is the random error term[33]. Predictions are accurate in both price components if the calculated differences in (1a) and (1b) are both 0. The hypotheses under rational expectations then imply that (1a) and (1b) cannot be rejected. Table II lists the means tests of (1a) and (1b) with t-values by institution, legal environment, and markets.

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[32] “The second-highest plus epsilon,” since the induced values are discrete and the highest bidder only needs to outbid the second-highest bidder with epsilon. This is true if the same agent has both the highest blocking and investment value. Otherwise, prices will be between the second-highest and the highest values (not studied here).

[33] Simplified predicted values can be calculated from the equations

(1a) NPV*blocking* = [fix – Vb-1] * Sum(1/(1+d)^t)

(1b) NPV*investing* = [Vi-1 * (1 – COGS – royalty) – (fix + investment)] * Sum(1/(1+d)^t)

where NPVblock/invest are the net present values from blocking and investing over the three periods. If the NPV from using the contract should be positive or zero (full truth revelation), solving these for fixed we obtain

(2a) fix = Vb-1 and

(2b) fix = [Vi-1 * (1 – COGS) – investment] – Vi-1 * royalty

This solution assumes that the Vi an Vb are constant over all three periods. In most cases Vb was constant but Vi was increasing. A solution taking discount rates into account was used for the actual experimental comparisons. In the demand-side competition (a Bertrand type of competition) prices would be defined at the intersection of these two lines. Substituting (2a) in (2b) we then get the following two means tests

(3a) fix – Vb-1 = 0 + u and

(3b) royalty – [(1 – COGS) – (Vb-1 + investment)/Vi-1] = 0 + u

where u is the random error term.

Table II. T-test of means for different contract markets over institutions and validity.

				Institutional environment														
Legal environment				**DA1**					**DA2**					**PO**				
Econ.env.		Vb-1		**f-f***		**r-r***		**N**	**f-f***		**r-r***		**N**	**f-f***		**r-r***		**N**
93/100	A	3	Inv.	**1.9**	***	**-7.9**	***	23	**6.9**	***	**-4.9**		7					
				5.56		-4.80			5.35		-1.5							
			Blk.	**1.1**	***	**2.9**		18	**5.6**	***	**-2**		5					
				2.47		0.87			3.73		0.31							
			Tot	**1.6**	***	**-3.1**		41	**6.3**	***	**-3.7**		12					
				5.58		-1.65			6.68		-1.17							
	B-	-7	Inv	**11.5**	***	**-52.7**	***	17										
				21.39		-11.83												
			Blk					None										
			Tot	**11.5**	***	**-52.7**	***	17										
				21.39		-11.83												
	B1	6	Inv	**0.35**		**-0.4**		17	**4.6**	***	**-2.3**		11	**0.5**		**1.4**		4
				1.03		-0.37			3.29		-0.77			-0.48		0.55		
			Blk	**-0.03**		**8.6**	***	21	**8**		**-9.2**	***	2	**-0.25**		**5.7**	***	4
				-0.13		5.41			1.33		-3.7			-0.33		2.32		
			Tot	**0.1**		**5.3**	***	46	**4.9**	***	**-3.4**		13	**-0.4**		**3.5**		8
				0.53		4.17			3.63		-1.28			-0.63		1.93		
	B2	7	Inv	**0.57**		**-0.8**		7	**4.3**	***	**-9.3**	***	15					
				1.18		-0.56			6.64		-6.8							
			Blk	**0.4**		**12.5**	***	22	**-1**		**2.9**		1					
				1.48		4.25												
			Tot	**0.45**		**9.3**	***	29	**4**	***	**-8.6**	***	16					
				1.9		3.74			5.75		-5.75							
	B+	10	Inv	**-1.4**		**9.5**	***	5	**2.5**		**7.4**	***	2					None
				-1.25		4.53			1		4.4							
			Blk	**-2.3**	**	**20.9**	***	13	**-3**	***	**29**	***	7	**-4.3**	***	**18.5**	***	11
				-2.64		5.90			-2.64		6.2			-11.1		11.5		
			Tot	**-2**	***	**17.7**	***	18	**-1.8**		**24.3**	***	9	**-4.3**	***	**18.5**	***	11
				-2.97		6.20			-1.42		5.02			-11.1		11.5		
	B++	12	Inv					None										
			Blk	**-2.4**	***	**36.0**	***	5										
				-6		5.50												
			Tot	**-2.4**	***	**36.0**	***	5										
				-6		5.50												
38	A	3	Inv					None					None					
			Blk					None	**0**		**4.2**		2					
											0.33							
			Tot					None	**0**		**4.2**		2					
											0.33							
	B1	6	Inv	**0.57**		**-4.7**	***	7	**1.7**	***	**-8.6**	***	3	**0.33**		**-2.22**		3
				1.33		-2.24			5		-5.5			0.5		-0.72		
			Blk	**-0.5**		**0.3**		10	**1.5**	***	**22.4**	***	12	**0.67**		**0.11**		3
				-1.63		0.12			5.7		5.04			1		0.125		
			Tot	**-0.06**		**-1.8**		17	**1.5**	***	**16.2**	***	15	**0.5**		**-1.1**		6
				-0.21		-1.00			7.1		3.34			1.17		-0.69		
	B+	10	Inv					None					None					None
			Blk	**-1.5**	***	**21.8**	***	13	**-2.3**	***	**36**	***	15	**-3.8**	***	**16.4**	***	5
				4.16		8.34			-12.5		10.02			-7.75		9.4		
			Tot	**-1.5**	***	**21.8**	***	13	**-2.3**	***	**36**	***	15	**-3.8**	***	**16.4**	***	5
				-4.16		8.34			-12.5		10.02			-7.75		9.4		
All	A,B,B+	Inv	104					59					38					7
		Blk	170					105					42					23
		Tot	**274**					**164**					**80**					**30**
								36%					48%					23%

f = fix bid, f* = predicted fix bid
r = royalty bid, r* = predicted royalty bid
B markets = ABs,ABq, and B contracts, i.e. split and non-split are included in the statistic.

These results indicate a strong support for the predictions of the fixed price for the B1/B2 markets (contracts with investment and blocking values) and DA1, PO institutions. These results hold for both levels of validity. When blocking, the royalty is overpaid, but not drastically. The tendency to overpay is consistent with an intention to block (no royalty paid), but the tendency to do so with some moderation is consistent with risk-neutral behavior (to be able to resell the contract if it does not turn out to be profitable). For DA2 the tendency is to overpay in fixed but also to consistently trade off the higher fixed with a lower royalty.

In particular, the fixed prices are within 0.5%-10% of the predictions across these markets. A test of fixed=0 and royalty=0 is firmly rejected. The "robustness test" with random alteration of B+ and B contracts show that DA1 slightly underpays fixed and overpays royalty with high propensity to block; DA2 slightly underpays fixed and overpays royalty even more (also with high propensity to block); and PO clearly underpays fix, overpays royalty and only blocks. The "responsiveness" to different validity indicates that DA1 prices are adjusted downward in the royalty (as the uncertainty in investing increases), DA2 overprices the fixed, and PO does not adjust any prices (overpaying the royalty).

This behavior thus appears consistent with prospect theory (Kahneman, Tversky, 1979): A decision under uncertainty would give priority to preservation of the value (fix/insurance). The investment value can be seen as being priced as a strategic option (royalty/gambling). If the decisions under uncertainty are made in the observed way, then this is also in support of the proposed informal theory to price the fixed component as an insurance. These results indicate support for the hypotheses of the blocking value expressed in the fixed price, if the prices can be expressed independently, and the royalty, the difference between the investment value and what is paid in fixed, expressed as a percentage.

Auction theory and experimental studies suggest that prices converge over time close to equilibrium no matter what the institution (with one-dimensional prices). Here, they don't appear to do that, although the linear prices appear to share a solution (they cross near the same price, which is close to the predicted price for high validity. See Fig. 18 and 23). The differences in linear prices between institutions appear to be stable. Furthermore, since patents are limited in time, the speed of convergence for different technologies matter. An inability to distinguish between contract values (the robustness) translates to the inability to discern between high and low-valued technology in the "real world." If one would rank the institutions based on the t-test statistics on mean prices: DA1 > PO > DA2 in *accuracy*, DA1 > DA2 > PO in *robustness*, and DA1 > DA2 > PO in *responsiveness* to changes in validity.

Table II-B. T-test of means for split contracts.

Institutional environment: DA1

Legal environment				non-split				Split			
Econ.env.		Vb-1	Vb	f-Vb1	f-Vb		N	f-Vb1		f-Vb	N
93/100	B	6/7	7/8	**-0.02**	**-1.08**	***	**48**	**0.7**	*	**-0.44**	**27**
				0.12	-6.55			2.34		-1.44	
	B1	6	7	**0.03**	**-1.06**	***	**32**	**0.28**		**-1**	* **14**
				0.14	-4.64			0.65		-2.31	
	B2	7	8	**-0.125**	**-1.13**	***	**16**	**1.15**	***	**0.15**	**13**
				-0.62	-5.58			2.96		0.39	
38	B1	6	7	**-0.56**	**-1.56**	***	**9**	**0.5**		**-0.5**	**8**
				-1.89	-5.29			1.18		-1.18	

B market refers to B1 & B2 markets
f=fix price paid
Vb1=Second highest blocking value, Vb=Highest blocking value
There is a tendency to trade off royalty for higher split fix prices; not statistically significant

To test for price predictions on split contracts, the same t-test of means is made, comparing split and non-split contracts, using DA1 data (highest propensity to split). Table II-B re-confirms the fixed price hypotheses, with price differences of less than 0.5% (!) from predicted fixed prices for high validity contracts, when the split contracts are taken out of the average. This result suggests *identification* of the fixed fee with the blocking value.

7.2 Comparison between institutions (dynamic efficiency)

The trading system is a dynamic microeconomic system. To calculate a "dynamic" efficiency measure, the optimal end state (as in dynamic programming) is used in the denominator. The numerator is the actual path taken through the system in the three periods in each round used, together with expected values at each decision point (the average value in the induced value range). The realized expected value is then divided by the optimal path's expected value. An initial calculation is made using data from the three institutions and two validity treatments. See Table II-E.

Table II-E. Instiutional comparison with respect to dynamic efficiency
***** INITIAL CALCULATION *****

Market		Institution					
Legal and Instit Env.		DA1	N	DA2	N	PO	N
93/100	**No-split**	26%	59	**37%**	30	19%	14
	Split	**40%**	13	31%	6	0%	0
	Total	28%	72	**36%**	36	19%	14
38	**No-split**	**19%**	16	16%	13	18%	7
	Split	16%	2	**29%**	3	0%	0
	Total	**19%**	18	18%	16	18%	7

The distribution of efficiency measures differ clearly between split and non-split contracts and the three institutions. The ranking is DA1 > DA2 >> PO for split contracts and DA2 > DA1 > PO for non-split contracts. The dynamic gains are thus clearly realized more for DA1. An explanation for this is that the values are more independently expressed in the DA1 prices; therefore, the price risk is lower, making role2 (trader) simpler and increasing the propensity both to split and to create quality contracts. Further analysis will reveal more information on efficiency and rankings.

The results are unsatisfactory for institutional efficiency. One would like to see values of 95%+. This result suggests that efficiency in impersonal exchange in patents is a difficult task to achieve for subjects. Additional institutional design work is needed to match comparable real world institutions (like stock markets). The results therefore provide an important clue as to why there are no organized markets yet. It is simply a difficult task. The recent attempts toward this goal have been made by intermediaries, who bring buyers and sellers together. This is the same pattern as during the time of the royal privileges, and particularly after the 1836 patent reform cited earlier. However, the stock market did not start overnight; private exchange, especially during IPOs is still very much used. Wall Street started due to a rain that forced people under the tree in the park where they met to trade. Here, they overheard each other's bids and asks and decided *everyone was better off* if these bids were written on a board that everyone could see. We're still waiting for that rainy day in the park when it comes to patents and buyers. Sellers may still be uncertain if they will do better with public prices.

7.3 Comparison between institutions (heuristic analysis)

The second question involves a heuristic study of the incentives (rules), messages, and information the institutional arrangements have on prices. This statistical study is designed to put the *future* into the linear prices. The complexity here is that there are two dimensions in the price. The bidding space is divided into 9 two-dimensional "price zones" defined by the minimum and maximum predicted values of the blocking and investment value ranges. This division turns the price data into a one-dimensional distribution of prices[34]. The first three areas are divided for the blocking value: below, in, and above the blocking value range. The same is done for the investment value (expressed in royalty). Thus, we have three boxes of royalty values for each fixed value, forming 9 boxes (compare the price data figures in section 5). They are then numbered from left to right, starting with the top boxes. This creates the numberings of the bidding space shown in Fig. 27.

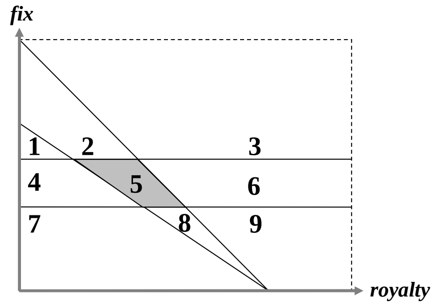

Fig. 27. Numbering of the **"**price zones" or "boxes" used in the statistical treatments. 5 indicates the predicted value.

The frequency of the number of prices in each box is calculated and becomes the one-dimensional dependent variable, more easily suitable for statistical analysis. Number (5) is thus the predicted value, "at the money." (4) indicates underpaid in royalty, "in the money," and (6) "out of the money." (1) is overpayment in fixed an underpayment in royalty; (2) is "at the money" in royalty and overpaying fixed; and (3) is "out of" the money in both prices. (7) is underpayment and "in the money" in both prices; (8) is "at" the money in royalty and underpayment in fixed; and, finally, (9) is underpaying fixed and "out" of the money in royalty. There are two tests performed.

a. First, a simple Chi2 is calculated pair wise for the different institutions by validity and market. This "similarity hypotheses" means that the null cannot be rejected if there is no difference in pricing incentives between the institutions. Results are shown in Table II-C.

[34] Ruling out a treatement based on a system of equations, an extensive search in methods to examine two-dimensional problems did not result in any "typical" treatment, in fact no examples were found.

Table II-C. Instiutional comparison with respect to prices

Pricing: B market		Price zone											
Legal and Instit Env.		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**N**	**Chi2 statistic**	
93/100	**DA1**			1	5	22	11	2		1	42		
												0.007 ***	
	DA2		2	2	2	2	1				9		**0.449**
												0.223	
	PO				1	4	1	2			8		
38	**DA1**				5	2	2	1			10		
												0.067	
	DA2				2	2	10				14		**0.096**
												0.007 ***	
	PO				1	5					6		

Robustness: B/B+ market		Price zone											
Legal and Instit Env.		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**N**	**Chi2 statistic**	
93/100	**DA1**			2	8	34	27	5	4	4	84		
												0.001 ***	
	DA2		6	5	5	6	2			4	28		**0.002 *****
												0.006 ***	
	PO				1	4	1	4	8	1	19		
38	**DA1**				5	2	4	3	1	8	23		
												0.161	
	DA2				2	2	10		1	14	29		**0.011** ***
												0.000 ***	
	PO				1	5		2	3		11		

The numbers in the table indicate the Chi2 probability. DA1 and DA2 show different pricing patterns for high validity, both in the B market and under robustness tests. The proposed explanation is that a seller, not wanting to lose (loss aversion again) a profitable blocking value, sets it on the high end, but not too high, to negotiate a trade-off with the buyers for a royalty that is still profitable if investing. Under low validity, this difference disappears, as investing becomes more uncertain and buyers appear less willing to take the risk to make the trade-off. DA1 and PO differ in robustness, as PO appears to not be able to distinguish between values under these conditions. In a “stable” technology environment (B-market only/high validity) DA1 and PO are similar; however, PO also underprices contracts (7). Since PO most closely resembles existing bilateral negotiations, high value technology may be underpriced in today’s personal markets as a result. DA2 and PO are also different except for stable technology environments.

b. Secondly, a multinomial logistic regression is run with the prize zones as dependent variables and six explanatory variables. These are: type of institution, level of validity, type of contract, contract quality, predicted fixed price, and predicted royalty price, given what is (actually) paid in fixed. The *future* is thus in the price (prize box) through controlled treatment and environmental variables, and the *present* is controlled for by using the fixed and royalty given the (actual) fixed price negotiated by the subject. The *past*, such as subject experience and past round prices, was not found to yield significant coefficients. Using the regression coefficients to *predict* probabilities of the price zones by institutions and validity confirms the general dynamics that can be observed in the figures, means, and Chi2 analysis. However, additional information can be drawn from the regressions in predictions; for example, the model may be suitable for predicting key aspects of patent and patent market policy or patent *trade* policy. Such policy issues are altering the presumed patent validity or the predictions, which gives an *absolute* measure of the changes in risk-bearing (fix) and risk-sharing (royalty) expressed in changes in the probability of a price zone. Running the predictions for a validity of 75% (about twice the low validity, 38%) yields an increase in *royalty* prices for underpaid contracts (zone 4) to predicted price (zone 5) with 50% probability (from 29% to 44% probability). This translates in inventors getting paid more (in royalty) by strengthening the patent system in a weak area (for example EU). Similarly, this translates to a reduction of prices (zone 5) in the high validity area (for example US) of -15% (from 51% to 44%).

Validity: Probability change of prices for predicted validity

Price Zone	38% →		**75%**	←	93%
4	0.36		**0.27**		0.22
		-25%		+25%	
5	0.29		**0.44**		0.51
		+50%		-15%	

Thus, *harmonizing* the patent system between a strong and a weak patent region (patent laws probably end up somewhere in between) yields gains for the weaker region and losses for the stronger region[35]. However, strengthening the patent system in the weak area while *maintaining* the superior strength in the strong area (no harmonization) may well allow the areas to *trade* in technology, increasing returns on technology as "patent assets" get *similar* validity. The "technology price gap" in terms of predicted prices (zone 5) goes from 22% (.51-.29) to 15% (.51 - .44), a 30% reduction. The market access risk of returns from technology per se is reduced for the stronger area's firms. Thus, having *competing* patent systems may strengthen *trade* in technology and lift the weaker area, while also lowering risk in market access for the stronger area[36].

7.5 Gains from trade (dynamic analysis)

Do we observe dynamic gains from trade, expressed by a propensity to split contracts? In formulating some hypotheses on systemic gains, I propose that a richer bidding language would yield more reliable prices as the price dimensions can be expressed more freely, which would lower the risk for traders when selling split contracts. The institutions with the richer language would then yield the higher gains. The number of *dimensions* of demand-side bidding is 2, 1, 0 for the institutions DA1, DA2 and PO. The propensity for: 1) splitting; 2) investing; and 3) investing in quality contracts are calculated for each institution. A ranking of the institutions is then made.

1. Using data from experiments studying the B1, B2 and B+ markets ("robustness test" data), DA1 yields a propensity to split *quality* contracts of **31%** (N=39, t-test for split=0 yields 4.1***), and DA2 yields **12%** (N=16, t=1.46) and PO **0%** (no split contracts). The t-test gives an indication of the propensity. I conclude that DA1 > DA2 > PO in dynamic gains measured in split quality contracts.

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[35] This argument has similarities in *predictions* to Krugman's "Technology Gap" model for international trade, where a case for "technological protectionism" is argued, but different in *analysis*.

[36] This proposition is in line with the historic development and use of patent systems to attract technology and technology development.

2. If we now include the outcome of the usage decision (invest or block) and use the propensity to invest, the *socially preferable* systemic gains defined as propensity to split and invest are: **10%** for DA1 (with propensity to invest = 35%, N=55, t=5.33 for invest=0), **9%** for DA2 (invest=75%, N=20, t=7.54) and **0%** for PO (N=7, invest=29%, t=1.54). This indicates that the propensity to invest, which has been determined to be generally higher for DA2 (see Table II), compensates the lower gains from trade and approach DA1. The ranking however remains DA1 > DA2 > PO, even when the social preferable outcome is taken into account. For low validity, the propensity to split is similar; however, including the propensity to invest yields **7%** for DA1, **1%** for DA2 an **0%** for PO, which tells the same story—DA1 > DA2 > PO. Since DA2 appears not to sustain the trade-offs between fixed and royalty under low validity (presumably due to risk of loss of contract), only the blocking option remains (again, see Table II). I conclude that two-dimensional bidding allows the prices to adjust in such a way that investment remains an option even for low validity, making a proposed ranking of DA1 > DA2 > PO for dynamic, socially preferable gains from trade.

3. The decision to invest in a quality contract by the inventor is a voluntary decision in the experiment. In part, it signals a willingness to cooperate with traders. This factor is thus part of the dynamic gains. The propensity to invest in quality contracts is 51% for DA1 (N=39), 50% for DA2 (N=16), and 37% for PO (N=7). Including this decision in the gains we get **5.3%** for DA1, **4.7%** for DA2 and **0%** for PO; thus, the ranking is the same: DA1 > DA2 > PO. The agents are thus able to coordinate investment in quality contracts, splitting and using to create dynamic gains in a *voluntary* environment.

Organized markets increase dynamic gains

It is also worth noting that PO, which most resembles today's bilateral exchange of patents, appears not to have the same incentives to sustain dynamic gains. This would suggest that organized markets, at least operating under the principles implemented in this experiment, would increase the socially preferable use of technology in the economy. With two-dimensional bidding (DA1) an increase in use of technology of **30%** (through split contracts) is observed and propensity to invest in technology including the split contracts increases with **10%** in the system. Since the linear contract is the most common contract, and inventors in some cases do achieve a fixed component, the results indicate that a substantially more socially favorable outcome could be realized through two-dimensional bidding.

7.6 Capital allocation (calculation)

In the experimental system, the agents are endowed with a discount rate for their values as a measure of the riskiness of the activity. The discount rate can be seen as a cost of capital for the type of agents in the economic system. A calculation of the average cost of capital in use is used as a measure of systemic risk (non-diversifiable risk in a portfolio sense). However, in the contract trade, risk in the technology is shared in a systemic way, including market access risk for new and existing products and services and not just financial risk. This reduces the uncertainty in returns from the technology. The capital allocation then directly reflects the gains.

The cost of capital in the system, calculated as the average of inventor (30%), trader (5%) and user (10%) capital, is compared between the institutions based on their propensity to split contracts (share the risk in the product market). A calculation gives: 18% for DA1 (30% split contracts), 19% for DA2 (12% split). and 20% for PO (no splits) both for high and low validity. As an indication of possible dynamic gains from trade using PO as a benchmark for today's personal exchange, the DA1 institution would reduce the systemic financial risk by **9%** and the DA2 by **4%.**

8. Summary and conclusions: linear prices and gains from trade

The conclusions are summarized under headings:

8.1 Linear prices and informal price theory

1. For the DA1 institution and the markets where contracts have both investment and blocking values (B-markets) the results are in strong support of the informal price theory for the *fixed fee* of the linear contract, i.e., the fixed fee should be *equal* to the blocking value of a patent. This result is particularly strong when the split contracts are taken out of the mean prices and then differ less than 0.5% from the predicted value (t=0.12 for rejecting the null that fixed = Vb-1). I conclude that what is priced in the fixed fee appears to be the blocking value of a patent. For the low value markets (A-markets) there appears to be a different pricing pattern for DA1 with what appears as a "floor" for the fixed fee close to the cost of creating a contract. The royalty is traded off to compensate for the higher fixed fee, similarly to DA2.

For the DA2 institution and high validity, the fixed fee is consistently *higher* than the blocking value, but never below it, and the NPV of investing is within positive territory, indicating that a trade-off with royalty takes place to compensate for the higher fixed fee. This trade-off disappears for low validity.

I conclude that the fixed fee includes the blocking value, but for high validity patents it also includes part of the investment value that is traded of a lower royalty (when the investment option is more certain).

For PO, the fixed fee is *lower* than predicted on average, but not significantly lower. This institution is closest to the personal and bilateral exchange common in today's patent markets, indicating that current market mechanisms without demand-side bidding would tend to underprice the patent.

2. A fixed fee appears to always be paid (fixed = 0 is rejected for all markets), leaving the "residual" value to be expressed in the royalty. For the DA1 institution and contracts with dual values, the results support the predictions of the royalty for *investment* use. The royalty is significantly higher than predictions for *blocking* use, making them unprofitable for investing. However, the royalty is still somewhat restrained, in spite of the fact that there is no payment of royalty necessary for blocking. An explanation is that a buyer may want to leave open the option to resell the contract, consistent with portfolio risk management through the secondary market, or might not want to reveal his intentions when bidding, consistent with strategic bidding behavior. Thus, there appears appear to be "two" prices, depending on how the contract is intended to be used. This result is contradictory to common criteria for a pricing system where the price should be the same independent of its use. In this experiment, the values were given for the three periods up front, reducing the uncertainty in the expected value ranges over time. If values were given only one period at a time (more like real market conditions) the investment option might be more important and the royalty "blocking price" might be closer to the "investment price."

I conclude that when contracts are invested in, the royalty paid is consistent with the predicted price, and when contracts are blocked, they exceed profitable investment options at the examined level of uncertainty over time. For the DA2, the royalty is depressed when investing as a result of trading off for a higher than average fixed, sometimes insufficiently though, resulting in losses. Since almost all contracts were invested in under DA2, there are no reliable results for blocking. For PO, royalty prices weakly support the predicted prices for investing. For blocking, the royalty prices are higher. Thus, blocking yields unprofitable prices for investing in most cases.

3. The pricing pattern expressing a preference for fixed fee over royalty appears to be consistent with prospect theory (Kahneman and Tversky, 1979), where an "insurance" (blocking strategy) is preferred to "gambling" (investment strategy). This result also gives support for the informal theory on linear prices proposed where the blocking value appears to be priced with the fixed fee as an insurance contract (risk transfer) and the investment value with the royalty (risk-sharing). The price for taking over short term market access risk (blocking) and long term market access risk (investment option) are thus negotiated in the price of the contract. In a similar analysis using Arrow-Debreu securities (Arrow, 1962), the two risks are separated into a fixed transfer price and an option price on "states of nature", that could be derivated on location, time, etc. The result is that there is no risk in the transfer price and all risks are spread over option markets for *each* state of nature. In the experiment using linear contracts, these risks are thus *in* the linear price.

4. Traders win contracts by outbidding the users, primarily using the fixed fee. This is consistent with the proposed theory that users are unwilling to pay more than the blocking value and lose a strategic option of blocking if the fixed fee is too high. The traders recover the higher fixed through the sale of the two split contracts. This suggests that inventors (who create quality contracts that can be split) and traders (who split) are able to coordinate their activities through the market mechanism to enable more efficient risk-bearing and risk-sharing in the dynamic microeconomic system. I conjecture that both the incentives of an impersonal exchange and a reliable price mechanism with public prices yield Pareto gains.

5. Boundary conditions of moral hazard result in re-pricing of the contracts to profitable levels for use in *one* dimension, investing or blocking. This suggests that voluntary trade occurs only for positive values of investing and blocking.

6. Secondary market trades only occur when primary market prices are too low, which was a rare event. This result shows that the primary markets tested are perceived as efficient in allocation of contracts in the dynamic system.

8.2 Institutional differences in price dynamics

1. Stable trading patterns emerge for the different institutions and validities, indicating different end-states of the dynamic microeconomic system (Nash equilibriums). This non-convergence to a common price suggests that demand-side bidding rules matter in pricing the linear contract, and that the richer the language / information (measured by number of bidding dimensions, 0, 1 or 2), the more accurately the linear contracts on patents are priced under rational expectations compared with the informal theory.

I conjecture that the most accurate prices can be observed when the demand-side can express the fixed and royalty dimensions *independently*. This suggests that two-dimensional simultaneous price negotiation is preferred in pricing the two-dimensional contract. Any limitation of bidding space therefore leads to trade-offs given institutional rules and validity with less accurate prices as a result.

2. Different legal environments (validity) mostly affect the willingness to share risk. A high validity encourages risk-sharing, i.e., use of the technology by investing in innovations. There is a shift in prices toward lower royalty prices for low validity. The fixed fee appears not to be affected as measured by price areas. This result may have implications for patent policy with respect to trade. A patent *trade* policy would include a focus on the price dynamics for fixed (transfer) and royalty (sharing), given changes in the legal environment. In particular, the claims structure, which decides which rights are granted, may be the attention of such policy so that the rights become easily divisible (field of use, geography and time) and tradable (contractual law link and validity in the divisible dimensions).

3. The treatments with randomly varying values in the B-markets ("robustness test") yield significant differences in the prices between institutions DA1, DA2 and PO as measured by price zones. The single B-market, where the technology environment can be interpreted as being "stable" (like marginal inventions), yields less of a difference between DA1 and PO, but differences remain between DA1 and DA2. Since PO is closest to today's mostly bilateral exchange markets in patents, i.e., personal non-standard licensing agreements with no public prices, differences between institutions suggest that fixed and royalty prices for inventions will be higher for both investment and blocking values under an impersonal exchange mechanism with demand-side bidding, resulting in a lowering of the risk in inventive activities.

8.3 Predictions of prices

1. A multi logical regression analysis of price areas allows for prediction of prices under different validities. A strengthening of a patent system from 38% to 75% presumed validity under the DA1 institution would yield a 50% increase in of the royalty prices in the rational price area for the inventors. Such a policy prediction suggests that the risk in inventive activities goes down. The same prediction, now compared with a patent system of 93% validity, yields a reduction in prices in the rational price area by -15%.

This suggests that a one-sided policy change to strengthen a weaker system may be preferable to a policy of harmonization, motivated by gains from trade. Harmonization may result in trade losses for the initially stronger system. Strengthening the patent system may promote trade in technology between the developing world and the developed world (similar to products and service). Key implication for the patent system may lie in the claims structure.

8.4 Gains from trade

1. Risk in inventing is lowered through the higher prices from impersonal exchange and high validity and split contracts with higher fixed yield (to outbid users). Therefore, this is a shift in risk-bearing and risk-sharing toward the user and ultimately the consumer, which changes the incentives of capital allocation in the economy to benefit inventive activities. I conclude that such a potential increase in inventive activity could be beneficial to economic growth based on development of technical ideas.

2. The dynamic gains from trade, expressed as propensity to: invest in quality contracts, split contracts and invest in contracts, yield DA1 > DA2 > PO. For split contracts, the values are 30% (DA1), 12% (DA2) and 0% (PO). The highest dynamic gains may be a result of a "reliable" institutional mechanism, reducing the price risk in reselling the split contracts. Such considerations may also be a motivational factor for the inventor to make the extra investment in a splittable quality contract. The dynamic gains including the socially preferable outcome of investing in the contracts yield 10% (DA1), 9% (DA2) and 0% (PO).

3. Gains from trade between different agents with different cost of capital would lead to a more efficient allocation of capital in the economic system. The propensity to split contracts reduces the systemic risk given the multiple users of technology and the lower cost of capital for traders (5%) and users (10%) compared to inventors (30%). A calculation comparing gains with PO (no gains) yields a reduction of -4% for DA2 and -9% for DA1 in the cost of capital in the experimental economic system.

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