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The Problem of Trading Patents in Organized Markets: A Dynamic Experimental Microeconomic System Model and Informal Price Theory

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THE PROBLEM OF TRADING PATENTS IN ORGANIZED MARKETS:
A dynamic experimental microeconomic system model and informal price theory

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Abstract

We are well familiar with the economic analysis of a patent system in terms of a temporary monopoly on *products,* benefitting from marginal process inventions, formulated under conditions of certain future demands. This article develops an experimental and dynamic microeconomic model useful for studying the patent system as a trade system, where patented technology is exchanged in organized *competitive* markets, under uncertain future demands. An economic system design is developed to study transparent *prices* of patents, dynamic gains from using a patent in multiple industries and the coordination of invention, intermediary and innovation activities using a linear contract on patents (fixed fee plus royalty on revenues). A trader is introduced together with inventor and innovator agents in order to multiply the value (use) of the technology. Three mechanism designs and two levels of presumption of validity of the underlying patent right are proposed. The analysis differs from previous work on patents, trade and economics in that the focus is on the competitive pricing of the rights themselves, using demand side bidding. An informal theory is outlined to price the dual values of a patent (investing and blocking). Based on this proposition tentative hypothesis are outlined for two initial experiments using the outlined economic system design.

1. Introduction[1]

The goal of this article is to develop an experimental and dynamic economic system design useful to study organized markets in patents. The problem studied is the "last step" in a historic transition from personal to impersonal exchange in ideas and some prerequisites for transparent prices on patents, dynamic gains from trade in the right themselves and coordination of technology search through prices. The main independent variables in this study are the therefore mechanism designs and patent system strength. An experimental approach is used since the mathematical challenges are currently prohibitive to model such a complex and dynamic system and there is no such market to produce data to be studied at this stage although many attempts are ongoing.

The standard example of the use of the patent system is that in which a firm use the system to protect an invention (a technical idea) and exercise a temporary monopoly on the *product*. The economic analysis of such a use has normally proceeded along the lines of

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divergence between private and social product in an integrated firm hierarchy. In this treatment, economists have largely used the excluding right of the patent, and marginal process (cost reducing) inventions. This is the treatment by Arrow (1962)on the allocation of resources for invention, Krugman (1990) in the technology factor of trade and the approach of Schumpeter (1942) of integrated markets. However, the patent system generally gives two rights, the right to exclude and to transfer or conclude licensing contracts[2]. To this end the optimal type of licensing contract has been analyzed as a transfer of the right under monopoly conditions in a product market. This is the treatment by Kamien (1992) and others. This treatment is interesting but does the take into account the competitive nature of technology. The second right establishes a *competitive* market in technology (not simply a seller's monopoly), with demand side bidders (competing for the technology). The conclusion of both these approaches has been the static gains from a patent system in terms of incentives to allocate resources for invention of cost-reducing inventions and contracting incentives in terms of private and social gains, leaving the dynamic gains from this often highly competitive technology market to further research.

It is my contention that discussing the patent system primarily in terms of a *static* product monopoly for integrated firms or markets may miss essential trade gains coming from trading the rights themselves between specialized actors in a dynamic and *competitive* market, with transparent prices. The static studies of the patent system may even lead to results which are not necessarily consistent with respect to how these rights are used and their effect on the structure the economic system (the model changes when competition is introduced).

A experimental and dynamic economic system is developed, expanding on the static microeconomic model for experiments of Smith (1982b)[3], to study three initial areas of interest: (i) competitive demand side bidding under different mechanism designs for public price formation, (ii) dynamic gains in the use of technology among specialized agents enabled by the patent system and (iii) price signaling between demand for technology and search for economically useful technology. Different auction mechanism designs and presumed legal validity of patents are the main independent variable. An informal price theory is outlined for a linear contract on patents and initial hypotheses stated. These questions begin to study the dynamic aspects of this exchange of which there are many more possible which I leave for future studies. A proposal for a price theory for patent trade is outlined to be able to form hypothesis on the experimental results.

I will begin with a summary of the static approach and then give an overview of the change in economic structure that has taken place since the beginning of the patent system in 1474. Followed by this historic and theoretical re-framing of the patent system as an exchange system is a detailed description of the dynamic economic system design intended to be useful for experimental studies. This part includes a section on institutional design for mechanisms designs differing in the integration of both information and rules, with hopefully quite different incentives to express willingness to pay/willingness to accept, forming the basis of the proposed initial experimental studies. An outline of a price theory then follows. Finally, some tentative hypotheses to begin the investigating the exchange system are formulated.

2. The institutional process and the changing economical structure throughout history

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[2] WTO TRIPSs agreement, Article 28:2, "Patent owners shall also have the right to assign, or transfer by succession, the patent and to conclude licensing contracts."

[3] The approach is based on Smith with institutions, I, and en economic environment, **e**, with changable tastes for technology through a discovery/sampling process with some limits: **s** = (**e**,I) . Here a legal legal genvironment, P, is added and the ability to "split" contracts according to claims on patents for limited exclusive use in different product markets. The contracts are tradable in a primary and secondary market.

A competitive market in technology

The traditional analysis tends to obscure the nature of the decisions that have to be made when trading patents in their own rights. The question is thought of as one in which a firm is investing in risky research and development activities, "production of information[4]", and should decide whether or not to patent the inventions in order to use them while protecting the ideas from being copied (defensive use) or to "block" competition from entering a business "too close" to its own business (offensive use); this is a problem of an anti-competitive nature. But this viewpoint is wrong from a trade context view. Here we are really dealing with a problem of *competitive* market nature. This market can also be thought of as a technology market for producers (innovators) and investors (traders) deciding to invest in an already patented technology. This market is developing in a direction that can be described from *personal* exchange through negotiations, e.g. licensing, cross-licensing, to *impersonal* exchange with prices through competitive bidding in institutions with rules.

However, pricing a patent is not the same as pricing potatoes or shoes. The patent has *two* sources of trade value based on its possible dual strategic use: investing in the useful technology or blocking someone else from doing so, making the competitive trading problem a two-dimensional one[5].

Blocking, or "sitting on", a contract is very different in terms of the risk[6] involved compared to investing in innovations and using the technology for products. The blocking value is also a value that is more "common" among agents. It does not matter who is "sitting on" it, it is still excluding others from performing certain competitive actions. Blocking allows the holder who is blocking to continue to earn money from producing based on its current portfolio of patented technology. This value is there even if the producer does not hold the contract, but remains strategically exposed to further development in the area of the protected technology, a value that can increase or decrease with time and be an investment even for a trader[7]. Up to 50% of patents who are renewed may be used in this way[8]. The one that can extract the value however is one that can sell such a contract to a producer who can realize its blocking value. Sitting on such contracts and then selling them is therefore also a strategy possible for financial traders not only inventors. The blocking use by a producer allows depreciation of current assets and/or timing of new innovations given the *market access* the firms currently have. The timing horizon, given the competitive environment and

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[4] Prof. David E. Andersson, pointed out the difference between information (codified knowledge) and tacit knowledge (skills, capabilites). This is dealt with in the patent application in the "disclosure" section where the invention must be described so that "a person skilled in the art" can reduce it to practice.

[5] In the optimal patent licensing literature, one dimensional markets are investigated, often studying either a fix fee licencing price or royalty price of a linear contract, negotiated in an auction.

[6] The word "risk" is here used for risk and uncertainty. Compare KNIGHT, F. H. (1921) Risk, Uncertainty and Profit. *New York: AM Kelley*. famous distinction between risk and uncertainty. The use here is that an insurance market can be created for risks - risks can be given a number and are 'insurable' - and uncertainty that has to be *managed* (through people, systems and intellectual property rights). The view on uncertainty appears to differ from Knight in that management and profits are not a complete lottery. At the INSEAD business school, Prof. in statistics S. Makridakis held for true that flipping a coin and hireing a manager to make the decisions were statistically equivalent in outcome, thus possibly supporting Knights view. Compare also prospect theory with 'insurance' and 'gambling' as decisions under uncertainty. Management of risk and perhaps in particular uncertainty appears to be an area of increasing importance to study.

[7] Here we are concerned with investors who take positions in technology as a business where the business model is to maximize the use of the technology. These companies sometimes are investment companies with patent pools or portfolios, which may give market access to the owners at more reasonable prices. This practice is not new and has been practiced strategically by competing producing companies, but it is fairly new when it comes to a separate business. These are not so called "patent trolls" who's intention is to extort rather than create value. The problem with "trolls" is related to creating incentives for innovations.

[8] Source: See Licensing Executive Society's statistical surveys.

current assets, is thus related to the cost of capital of a firm in deciding between projects (using discounted net present value of cash flows from operations). The blocking value can therefore be seen as protecting the market access of current and future products from more competition, extracting more money by limiting competition from new product innovations or product "cannibalization"[9]. There is a similar strategic use in "corona patents"[10].

Innovating new products by investing in using the patents is much more a private value to a specific company or industry. Here the technology is being used to *create* a new competitive advantage through product innovation together with current technology portfolio of the company. The risks with respect to market access are here higher, since developing a new product to create more market access is typically more uncertain than producing current product mix[11]. However, since competition and needs change, innovation is a strategy companies need to assure long term market access.

Allocation of risk bearing and risk sharing

The intent of the patent system is to create incentives to innovate not only to invent, i.e. *useful* inventions[12]. If trade in patents is to be included in the economic equation, its purpose should be to achieve a more optimal allocation of the inventions with respect to managing the market access risks in the innovations. If measuring market access risk by volatility in revenues (sales), the volatility in current sales are typically much less than from new products, making the risk of blocking lower than investing. This suggests that blocking is a less risky strategy than investing. In trading this right competitively both the investment value *and* the blocking value of patent claims have therefore to be taken into account. The contention is therefore that the instrument traded has to be two-dimensional, allowing the expression of the two risks independently. Such an instrument is the *linear contract*[13]. I will come back to the reasons for using the linear contract in section 3. For now the conclusion is that to encourage organized trade of patents its two-dimensional value would need a two-dimensional contract to allow efficient trade with respect to its economic use and to manage market access risk in customer relations and the economic system as a whole.

Historic development

The development of organized trade can be historically framed by trade in technology that shifts from *personal* exchange to *impersonal* exchange[14]. See figure 1.

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[9] Cannibalization is a concept in management where own new products take market share from existing products, "cannibalizing"on the market share of the existing products.

[10] Corona patents refer to patent that are granted for invention building on, or around a basic patented technology. Once the basic technology is free, the corona patent holders exclude basically any future development for the original patent holder. The most famous case here is Xerox versus the japanese photocopy industry who were able to develop new applied technology and once the basic patents were expired, caused a severe blow to Xerox.

[11] Product mix is a concept in management where the market access risks are managed by not having "all eggs in the same basket". Different products can target different market segments to spread the risks in more than one product market. A good product mix strengthens the relations with customers and reduces the market access risk.

[12] Plant asked the question that the crises in the 1930:s migh have a relationship by creating "too much invention of the wrong kind" (1934), p51.

[13] For the linear contract literature see Tirole, Lafont, Kim and others.

[14] For a broad discussion of the theme of "personal to impersonal exchange", see (Smith 2003) and (Smith 2007), Rationality in Economics: Constructivist and Ecological forms, Cambridge University Press. Also Grief (2002) "Institutions and Impersonal Echange"

Personal exchange → Intermediaries → *Impersonal exchange*
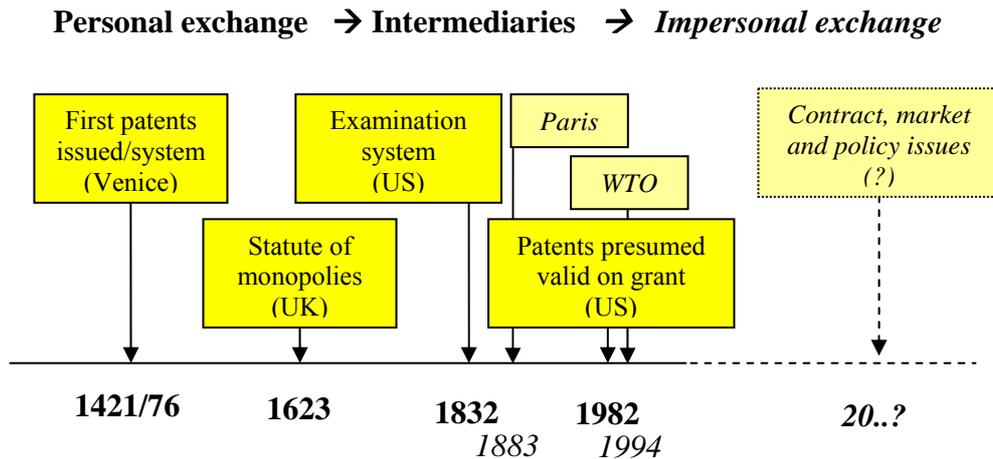
Figure 1. From personal exchange towards impersonal exchange in patents.

Personal exchange refers here to the current trade in patents, mostly licensing[15]. This use has seen a rapid growth in the last 20-25 years, especially in the USA[16], passing 1tr$ according to widely accepted but rough estimates. The exchange may include intermediaries (patent lawyers, accounting firms, investment and commercial banks, etc…) in the contractual and valuation side of these transactions. Intermediation is not new and has been studied by economic historians with focus on transactions, notably the effects of the US patent reform in 1836. The reform added the "invention" of the examination, in addition to simple registration which had previously left validity of uncertain claims up to the courts. Now patents could be *presumed* valid upon grant which led to the evolution of a new industry of specialized patent *traders* emerged (Lamoreaux and Sokoloff, 1999, Lamoreaux and Sokoloff, 2001). In the 1400s the first patent system was established in law (Venice 1474) creating "industrial monopolies" making trade secrets public. In 1623 in the UK (England, 1623), these "industrial" monopolies granted by the Crown were abolished and replaced by 14 year patents on products and processes which, as it appears, created the two-dimensional nature of the contract by opening the door to blocking since the value of the previous "industrial" monopolies were in the production. In 1982, the presumption of validity, previously given to the society, was returned to the inventor, who is taking the risks in the inventive process, effectively creating a situation comparable with ownership of physical assets in terms of presumed validity[17]. In the international arena the Paris convention from 1883 turned the patent system into an international system (through a priority year and national treatment) and the WTO/TRIPS agreement declared "minimum standards" for all member countries (a

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[15] or transfer between companies for a fee or cross-licensing or both, within companies, for policy reasons, tax reasons, cost reasons, within pools of patents, to simplify, reduce patent "stacking" and cost of market access, within standards, typically under RAND conditions, patent portfolio securitization, a bond that in the rare cases so far yields licensing revenues, other forms of bilaterally negotiation and contracting, or initial bankruptcy or specialized "patent auctions" in one dimension (fixed fee). RAND, Reasonably And Non Discriminatory, terms is an agreements often used with standards to allow inclusion of patented technology in a standard, making it more attractive and useful, without exluding any market actor. This is a common activity in the telcom industry where interoperability is a key. The competition then moves to the product side with design, tradmarks thus other IPRs and at the same time the patent owner can secure a "reasonable" royalty from the technology. This is such an important field that Sony chose to make the Sony-Ericsson joint venture on the handsets since is was too costly to license the technology (Source: a public inverview with the CEO of Sony at the time).
[16] A federal patent circuit court was introduced in 1982 as well as a rule change comprising that patents granted by the patent office should be considered valid when challenged , creating a more asset like right of patents.
[17] In the USA the presumed validity went from 38% to 93% during the 10-20 years following the 1982 decision.

contested agreement) (Paris, 1883, Geneva, 1994). A theme that appears to be motivational for this institutional evolution is the importance for economic development through technology *trade* (import/export from the city state level to the national level to the international level).

Trade secrets have thus received public protection, public disclosures and become tradable in an *impersonal* sense, over a process of more than 500 years. What appears to be the current direction is *public* prices: making technology trade an even more integral part of efficient economic development. The focus for the economic system designer is therefore impersonal exchange imbedded in a testable market institution to study the prices and gains from such IP trade. The buyers and sellers will interact through rules set by the "intermediary" (the institution). As a result, bidding and clearing prices will become *public*. Such trade with *public* prices accentuates the *dynamic* side of an economic system where many inventors can sell, with help of traders, to many innovators for multiple technological usages.

The question that has to be decided is therefore how the competitive prices of a two-dimensional contract on patents ought to be determined (theoretical price) and under which institutional arrangements we can observe the most accurate prices (with respect to predictions) as well as possible gains from trade given the presumed validity (legal institutions).


3. The Dynamic Microeconomic System Design

The impersonal exchange testable market studied is part of a microeconomic system design experiment using trained cash-incentivized subjects[18]. The economic environment, e, the institutions, I, and the legal environment, L, are designed to capture the *principles* of the patent system, including the dynamic effects: the two-dimensional nature of the pricing problem, the decisions that agents specialized by type of activity, invention, trade and innovation can *do* dynamically under induced uncertain private values of the patented technology, and only presumed validity[19]. Fig. 2. gives an overview of the designed system.

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[18] One here commonly makes the distinction between "naturally occuring markets" that can be observed in the economy and "design markets" which are constructs whose properties are examined in a laboratory experiment or in a game theoretical mechanism design analysis. The contention that the designed system is a real microeconomic system allows for paralellism between the designed and the observed economy at some level of abstraction, and is supported by the fact that real people make real economic decisions recieveing real cash payments for their gains. If the payments are "salient" enough then other preferences are argued to be suppressed and the profit incentive dominate behaviour, thus cash-incentivized subjects. See Smith (1982).

[19] All systems are based on principles. If the principles are working, we have a functioning system. We can study how these principles are working in this complex system of trade in IP through laboratory experiments and attempt to draw inferences from the outcomes with respect to these principles. Uncertainty in private values is introduced by given the values in a range from a random distribution rather than fix values. Under rational expectations, the value "used" by a subject making decisions on prices would then be the mid-point/average.
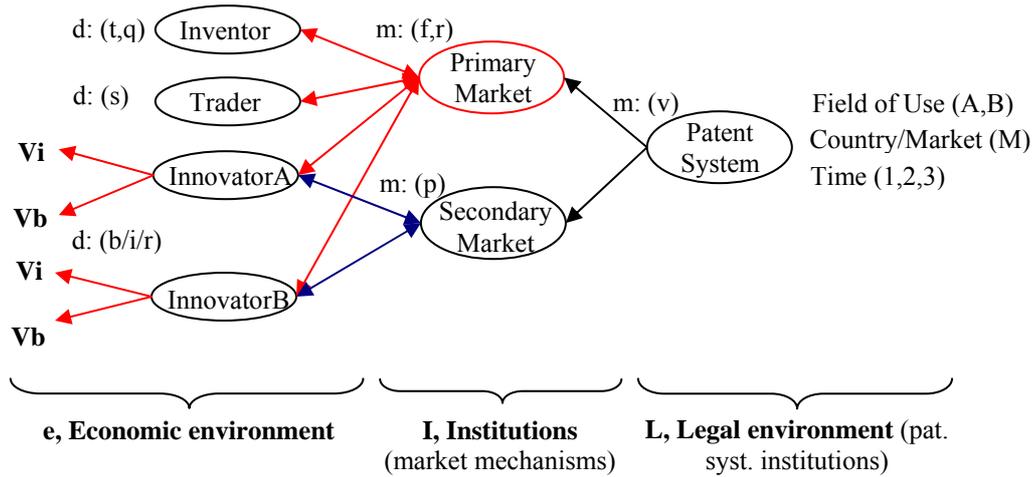
Figure 2. The dynamic system design: **s**, to study prices and gains of the patent system during-patent time. **s** = (**e**, **I**). **I**=I1, I2, L. Vi/Vb=induced value ranges for investment/ blocking options. m(f,r), m(p) = ask/bid. m(v) = validity message. d(t,q)= tech.focus and quality decision by inventor. d(s) = decision by trader to split contract in multiple usages. d(b/i/r) = block/invest/resell decision by innovator.

The inventor creates a contract to trade having a certain technology focus (t) and quality, q, using decision d:(t,q). Traders can split, s, using decision d:(s).The agents send messages, m:(f,r), expressing the fixed fee (f) and royalty (r) in the primary market. In the secondary market a single price, p, is negotiated using message, m:(p). The patent system has a certain presumed validity, v, which is sent through message m:(v) to the agents. Innovators can block, b, invest, i, and receive a value Vb or Vi, using decision d:(b/i). In period 2 and 3 innovators can also resell, r, using decision d:(b/i/r).

By studying the system at a level of institutional principles, attempting to choose the environmental design parameters and the uncertain private values to approximate what exists today in the economic and legal environments, we can examine in a repetitive and controlled manner, prices and adjustment processes and the dynamic effects of the designed institutions on the system as a whole (Pareto gains). Using this approach policy and strategy conclusions can hopefully be more easily drawn[20].

Since the patent system is used in a complex way, I propose to start the description of the system by a description of the parameters and assumptions (legal environment). The decision making inherent to the principles is then discussed (economic environment). Finally, a simplified mechanism design is presented (institutional environment).

3.1 The legal environment

To introduce the patent system as an independent variable, the typical *economic* environment including economic agents, commodities (and resources) and certain characteristics of each agent, is extended to include a *legal* environment. This makes it possible to vary the presumption of validity of a patent which affects the risk in trading patents. In the environments tested the presumed validity is varied between "high" and "low". The high value used, 93% probability of validity during the life of a patent, is chosen to match current

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[20] This total system approach has been advocated by Coase (looking at a problem "in total and at the margin", (Coase 1960)) and others as a way to draw conclusions for policy that would have some relevance to the actual situation.

approximate levels of US PTO patents[21]. The low value used, 38%, is chosen to match the level of US patents prior to the 1982 change in burden of proof (a patent granted by the patent office is now presumed valid when challenged in court, giving the benefit of the doubt to the inventor) *and* to match current approximate level of EU (EPC) patents[22] (currently also approximately 38%) that have the "pre-1982" US burden of proof doctrine (a patent granted by the patent office is presumed not valid when challenged in court, giving the benefit of the doubt to the society). This shift in the benefit of the doubt to the agents who are actually taking the risk in purchasing technology may have been the necessary step to make the patents truly tradable [23]. The system thus provides the possibility to study prices, usage (innovation/blocking), social gains (and possibly other economic consequences) for the alternative legal patent regimes (a question of principle).

The innovative use of the patent right (technology) can be increased through derivates made possible through the patent system's design: fields-of-use (claims), geography (designated countries) and time (excludable years). "Splitting" the right into several fields-of-use (for different product innovations) is configurable in the experimental environment. The periodic renewal of patent rights fee used is set to zero in the initial studies but remains configurable as an institutional parameter for future study[24]. The economic time horizon is set to 3 periods, representing the typical 20 years of legal value.

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[21] Souce: EPO's estimates of validity for US (93%)and EU (38%) around year 2000.

[22] Note the important distinction between the PCT route of a central *filing* system for applications and the national (for example US) and regional patent laws (for example EPC) granting the rights. The "international" patent system is still the Paris convention (1883) granting applicants national treatment and a priority year to file in each and every nation of the treaty, i.e. a system based on these two *principles*, and not a 'harmoinzed' patent law. The UN's PCT system, administered by WIPO, has for the last 4 decades been developing towards a real international system. Recently, through Chapter II of the PCT, the system approaches the status of a patent *granting* system by issuing a preliminary reports on patentability, moving the PCT closer to an international patent system. The main "obstacle" here seems to be a difference of principle between the US system of "first to invent" plus a "grace year" to file a patent application for the invention and the EPC, JPO and rest of the world systems (ROW) of "first to file". The US system gives the inventor the patent in his own rights (the inventive activity). The ROW system is an system where the state decides the priority date by receiving an official application (the administrative activity). The US system thus gives the advantage of being less administrative by principle, however at the price of an elaborate case law to prove the date of invention, if the patent is challenged, creating uncertainty of validity. Most resently (2009) a first-inventor-to-file system is proposed in US to "bridge" some of the differences and making the US system also a filing system. The current trend towards harmonization of patent laws challenges the historic policy use of the patent system as creating *national* competitive advantage. Whether "competing systems" or "harmonized patent laws" is the best for world trade and global economic development is here a question. Here the focus is on the trade once the patents are granted and any uncertainty in legal validity is parametrized by "presumtion of validity" as a percentage that is uniformly distributed, U[0,100].

[23] This shift is often referred to as the beginning of the "pro patent" era with emphasis on the claims (the granted rights). Previously there was a "pro society" era, with an emphasis on the disclosure of the invention (what is made public about the invention).

[24] One way of dealing with renewal fees are exponentially increasing fees over time. This is in practice at for example the EU with EPO. The economic argument is that to create incentives to innovate, the cost of renewing the patents should be taken out on the innovations when and if they are likely to be profitable for the inventors. This takes place years after patenting the invention and the innovation is introduced in the market. Recently, there was a proposal in the US to introduce increasing fees over time. Protection for inventions that are economically valuable are then renewed by its owners and others are dropped, potentially making access to technology easier and incentive to develop valuable technology increases. How much innovators should give back to society in monetary terms is a contentious issue but the issue here is also about creating economic incentives to use the inventions in innovations. This second point deserves a more than a footnote though.

3.2 The economic environment

3.2.1 The economic agents

The economic environment is a fixed environment in this experiment; the independent variables are the institutions and the legal environment. To study the transfer of rights aspect we can distinguish between three activities: inventing (creating and selling the rights), trading (buying and selling, to maximize investments in the rights in potentially multiple innovations) and innovating (buying and investing in using the rights). These activities are all more or less present in today's *personal* exchange but the activities are still *mostly* carried out within a single firm (coordinated in a hierarchy). The rapid increase in licensing of patents and other IP during the past two decades is changing this. In the experimental environment, these activities are executed by the specialized economic agents, each performing only one of the tasks, making it possible to study different pricing mechanisms for patents (coordination in a market with prices that are public). The specialized economic agents will be referred to as: inventor, trader and innovator. This organization of agents is motivated by differences with respect to the risk that has to be managed (uncertainty in market access) in each type of activity, thus they may have different costs of capital (referring to CAPM or the inter-temporal ICAPM with "betas" for validity, etc.)[25]. This assumption can be seen as supported by the fact that venture capital typically asks around 30% in return, financial institutions 3-5% (3.5% for long term return adjusted for inflation and taxes[26]) and shareholders in listed companies 10-15%, dependent on industry. In the experiment 30%-5%-10% are used for the respective categories of agents. This key economic characteristic of the design allows a new type of agent to be introduced who invests in patent rights, the trader. The specialized inventor firm is also a new kind of company, operating under a high risk business model, possibly requiring more capital to succeed through trial-and-error R&D projects. This is an increasingly important business model for many inventive start-up companies today. The cost of capital can then be calculated for different systems, indicating changes in the systemic risk[27]. A strategic problem with the specialization may be that not all information with respect to the patented technology can be transferred, like for example know-how[28]. One way to deal with this could be to also add a second contract option that guarantees transfer know-how to the buyer of the contract traded. Future inventions in the same field may have to be bundled in order to not block a potential

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[25] This assumption is in fact a tentative *proposition* that the boundary of a firm may be organized in terms of managing genuine *uncertainty* specifically related to ideas (market access). This means that there is a proposed difference between managing uncertain market access related to *new* sales (revenues from new innovations) and cost (revenues from old innovations). This may have similarities to "cost of carrying out a transaction" or "marketing costs" (Coase 1937), or differ in terms of investment costs, expressed by the cost of capital, as a determining factor for firm organization, reflecting risk in their long-term market access of a firm and how well they manage these risks through people and systems (in particular information systems). The argument is here that the proposed division of activities actually is based on difference in the uncertainty of carrying out that activity. This would be reflected in a competitive market priced access to capital, the cost of capital. The experimenal economic environment includes this parameter as a controlled variable by the experimenter but experiments making it an independent variable could be designed.

[26] Ref. to personal communication with B. Lev.

[27] The systemic risk here refers to the Capital Asset Pricing Model (CAPM) and Intertemporal CAPM (ICAPM) method to calculate the *systemic risk* (the alpha) of a market and a *project risk* for a project (the beta(s)). This is a mere calculation excersise in the experiment, based on endowed typical cost of capital of the agent types, given the actual allocation of risk bearing among subjects of different agent types. As mentioned elsewhere the design may be used to make this a more endogenous decision in future experiments.

[28] Information can and is also kept private as trade secrets, exposing the buyer to further inventions by the sellers. Such behavior of course drives down the price for an invention. This problem is thus related to the disclosure requirements of the patent, an issue of policy.

buyer in the future. Institutions which facilitate bundling are possible but seriously more complicated and will be left to future study. The primary purpose at hand is to limit the study to possible gains from trade of *publicly* disclosed information through the patent system, which may exclude some important second order strategies from the study that may be of consequence in naturally occurring markets.

Inventing typically includes extensive research often performed in an organized fashion by whole teams of highly educated professionals (up to 40% of inventors have a PhD degree according to a recent EU study[29]) working with colleagues internationally or over the Internet which has turned research into a global activity today[30], and patenting to receive the patent right for granted claims, strategically selecting validation states in the process[31]. The "pre-patent" phase involves activities and decisions of basic research by universities and governments, joint-research ventures, "patent races", etc, where the patenting policy may differ between actors, thus not all commercially useful inventions are patented, for a number of reasons (military use, patentability, detectability, also other IP may be favored, like trade secrets, etc). The patenting phase can be thought of as a process producing "patent products" for certain country markets that can be used for innovation purposes. This practice creates a "portfolio" of patents which represent "technology assets" of a company. The *patenting* process is highly specialized and external 'patent lawyers' here do much of the work today thus then "inventor agent" is at the minimum includes the inventor and a patent lawyer[32]. This service is a rather costly and comes at the initial stages and is included in the model as a *cost* of creating a contract (not a special agent). A simple portfolio of one (1) contract is included in the design and only one market (validation state). Neither the "pre-patent" nor the "post-patent" use of technology is included in this design. The contract cost varies depending on the 'quality' of the patent. High quality patents cost twice as much as low quality ('standard') patents.

Innovation typically includes extensive market research, product development, marketing, sales, product life cycle management, product mix strategy and patent portfolio management as well as the use of know-how and technology that can be patented, is expired or non-patented. The innovation phase is the "using phase" of the patent product. "Spill-over" effects and other "post- or pre-patent" effects are not explicitly included either, except the "signaling" of the value of a contract that takes place through the market prices.

Trading in patent products today typically includes different kinds of licensing agreements: the purpose being to free up present (licensing) and future (potential licensing) market access,

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[29] Ref. to European report on invention, GAMBARDELLA, A. & AL., E. (2005) THE VALUE OF EUROPEAN PATENTS EVIDENCE FROM A SURVEY OF EUROPEAN INVENTORS. *FINAL REPORT OF THE PATVAL EU PROJECT, Contract HPV2-CT-2001-00013, January 2005.*

[30] This "large corporation" situation does in no way exclude the individual inventor or SME, who have similar processes, in particular global due to Internet. Also the majority of patents are granted to large corporations who typically have research organizations. It takes research to be in the patent business. All resesrach frontiers are in practice globally accessible (withing their publication sphere: private, public, government) very shortly after discovery, making research a global activity, which is the main point here.

[31] Validation strategy is very important from both a competitive and a cost perspective. Validation is typically decided by three criteria: Presence of customers/competitors, presence of possibly competing manufacturing facilities, presence of compteitive research firms (since the patent system also includes excluding rights for research). This very complex *market oriented* approach technically results in a number of validation countries for a patent. Since the cost of a patent is about 1m$ during a patent's life (Source: Private US lawfirm), and even the largest companies have limited patent budgets, this strategic validation typically results in about 7-8 countries or even less, across all technical areas, the exception being pharmaceuticals who see a competitive threat in "every local pharmacy", thus having much wider country coverage (Source: EPO communication). Previously for many companies the absolute *number* of patents was an important strategy. This is changing and a renewed focus on "quality" is made. Those patents are also more tradable which may be the key a motivating factor.

[32] Prof. Rassenti suggested that this agent was very important.

and for specialized actors, like patent lawyers, enhance the possibility to "split" the patent products into multiple fields of use (claims), geographical markets (validation), time, exclusive or non-exclusive for multiple licensing of the same technology. Traders have incentives to "maximize" the available use of the patents across all innovators, making them of key importance to improving gains from trade. In the experimental model the dynamic adjustment comes from traders "splitting" one of the contracts into two "fields of use".

3.2.2 The security traded

In section 2 it was argued that the contract traded had to be two-dimensional to accommodate for the simultaneous investment and blocking values of the patent right. The experimental environment will use a linear contract with two components: a fixed fee plus a royalty contingent on sales (revenues)[33].
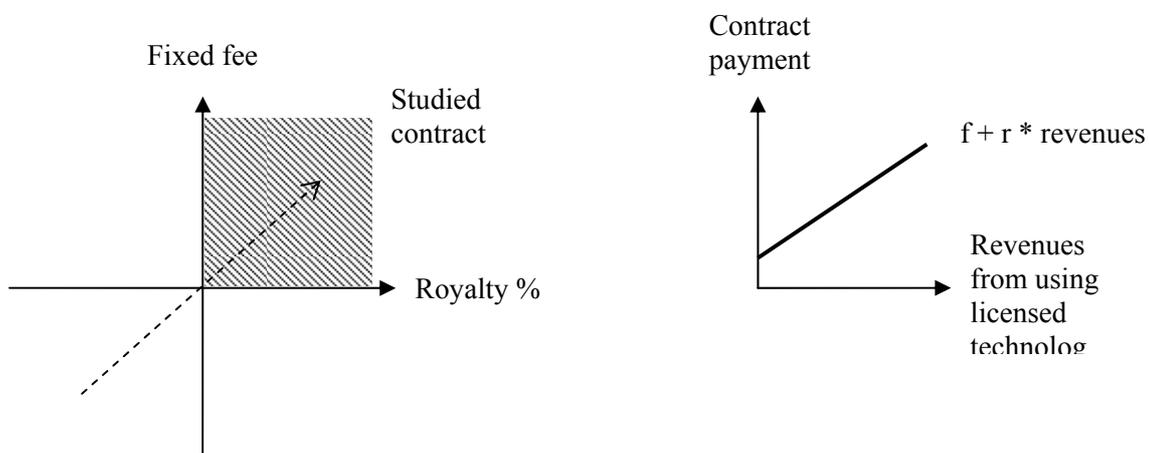
Fig. 3. The tradable linear contract: components and payouts.

The left part of fig. 3 illustrates that the linear prices are made up of combinations of fixed and royalty payments. The figure to the right illustrates the payment from a holder to an issuer for using the rights in innovating for blocking. The contract is tradable, meaning that a holder who once bought it (in a primary market) can re-sell it to anyone at will (in a secondary market). The patent itself is not traded, its ownership remains with the inventor, but the contract is, licensing all or parts of the granted patent rights in the patent claims. The contract

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[33] The contract to use has been the subject of considerable attention and challenge. Prof. V. Smith, first drew my attention to the fact that a "one-dimensional" contract is not different to that of trading potatoes or shoes. This lead the thought to question the contract itself, whether it would be suitible to trade IPRs. A key input was given by Prof. D. Porter who saw similarities between the risk sharing problem discussed and "sharecropping". That literature search led to J. Stiglitz (1974), Incentives and Risk sharing in sharecropping, which in turn let to the literature on linear contracts (Tirole, et al). Also, input from an inventor suggested that a fix+royalty would be preferred although rarely possible, strengthened the author's belief in using a linear "two-dimensional" contract. When the two-dimenstional nature of the value became clear, it all seemed to explain the rationale behind why inventor agents prefer such a contract and buyers accept such a contract in some cases. Special data from a unique source on patent licenses confirmed that linear contracts with some fix payment were used in 50% of the cases and only 13% with an annual minimum payment, a truly linear contract (Source: RoyaltyStat Inc). The observed use of contract and the theoretical propostion based on management of market acces risk thus coincide so some extent.

is binding. This construct makes it possible to "split" the rights into several contracts as described in section 2. It is thus the *marginal* value of the technology that is priced[34]. This leads to a system where the total value, given by gains from trade, and the marginal value can be studied.

A key aspect of the contract is that it expresses both risk *transfer* (the fixed fee) and risk *sharing* (the royalty) between buyer and seller. Thus, in the contract, risks are allocated through the royalty. This may be seen as an alternative to the Arrow-Debreu security (Arrow, 1962) of optimal allocation of risk through derivates markets, one for each "state of nature".

Another aspect of the linear contract is that it can theoretically be extended to allow negative values for the fixed and royalty components, which would then represent common usage of financial capital similar to that of debt financing of firms. For the purpose of this experimental environment, only positive values are explored[35]. In extreme cases such contracts can be interpreted as if an inventor-innovators (the hierarchical model) are bribing other innovators to produce less to realize monopoly product pricing (Katz and Shapiro, 1985), p26. However we are here concerned with a specialized agent model where both dimensions are negotiated and there is *competition* in technology. With positive component values (as studied) the contract could possibly be seen as creating a new use of capital. A trader can, by taking a position in a certain contract and split it, finance the time between invention and innovation and gaining from a potentially increased use of the technology. This trade potentially reduces the market access risk for the trader's position and allows longer term financing to be made (the 5% mentioned above). This amounts to a new use of capital, to fund *productive* patent portfolios, or, trade in technology.

There are two reasons for the choice of the linear contract in the model: empirical and theoretical. Firstly, the linear contracts are the most commonly used in private exchange (although they are typically non-tradable). A fixed fee is typically paid upfront followed by an annual royalty typically related to revenues (sales) or number of units sold (unit sales). Patent renewal fees are typically paid by the buyer (the presumed user of the patent). The rationale for this contract type appears to come from the moral hazard problem with respect to its usage. If the contract is *never* used in a product, the inventor gets nothing if there was only a royalty. This is a problem commonly expressed by individual inventors. Their patents end up in the "drawers" of the buying company due to "changing priorities" of the buying firm or no intention to do anything in the first case except "block" a possible competitor. The fixed fee, it is argued, creates incentives for the buyer to *do* something with the contract (presumably to recover the fixed fee). Without this fee there may be little action. However, it also appears that it is getting increasingly difficult for inventors to successfully negotiate a fix fee at all[36], thus reducing the incentive effect argued for.

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[34] Recently the federal patent court in US changed the principle on which payments in infringments cases should be based from the "total" product value approach to the value that is attributable to the product from the infringed technology. This could be a recognition of the fact that 100ds and sometimes 1000nds of patents are used in a single product today and that they contribute individually. This could be seen as a "marginal value" of technology to a product.

[35] A positive fix and a negative royalty is similar if not equal to a venture capitalist lending money to as start-up and asking a royalty in return. To avoid moral hazard related to the use of funds, the VC also takes ownership in common stock a board seat, etc. The capital transferred is used for innovation purposes. A negative fix and a positive royalty is similar to a spinn-off venture where the mother company is asking for cash back and at the same time paying a "performance fee" to the company for using the IP. Also here common stock are often used to have control over activities. Niether of these may be voluntary due to the moral hazards (additional contract dimension are needed to enforce investment in the contract and not blocking it such as common stock or joint ventures). A negative fix and royalty is similar to a firm financing all costs through internally generated funds and debt, i.e. the hierarchical model.

[36] Ref. to personal communication with Karl Derman, Polhemprize 2007, one of Sweden's most successful serial inventors, who has jointly with major Swedish companies developed a range of products with global reputation.

Secondly, a linear contract covers the problem of two-dimensional *value* having nothing to do with the moral hazard. I propose to illustrate that here in summary, then more fully in section 4. The argument is that a patent's blocking value is formally similar to an insurance contract, in which a *cash payment* is typically exchanged for insurance to cover irreversible losses, *transferring* the risks from the seller to the buyer. This is similar to what the blocking value does for a holder: it "insures" him against irreversible losses of market access (sales). The investment value is different in that a contract used in innovating a new product is accompanied by risky investments in development and marketing. Increasing the market access or keeping long term market access is not as "predictable" as in the case of blocking to keep existing market access (typically accurately predicted by companies and analysts alike). A risk sharing agreement over time is needed. Here the proposal is simply to treat such use as investment in a project and value it at its Net Present Values (NPV) minus a royalty on "success" (revenues), minus what is paid in fixed fees, discounted at the project's cost of capital (a project beta[37]). This reason can be summarized as managing short term market access by limiting competition by blocking using a cash payment (which is rather certain and can be based on *expected* revenues in an insurance like manner), and long term market access of increasing competition by investing in new innovations based on the acquired technology (which is rather uncertain and therefore the risk is shared by a percentage of *realized* revenues). Finally, due to the inter-temporal nature of the problem, preferences and market conditions may change during the life of the contract and the owner may wish to make changes with respect to technology portfolio. The tradable linear contract can be seen as an excludable, non-rival "security" that is traded under presumed validity of the underlying patent rights. Given these considerations, the linear contract appears to handle the risk mitigation requirements observed in the world.

3.2.3 Agent characteristics

Inventors can (endogenously) decide to 1) enable traders to be buyers just as innovators by investing in a quality contract, and 2) select a certain technology focus for the contract (used only in the second experimental environment). Traders have the technology (knowledge) to split a contract in two non-competitive fields of use and can, if they win a contract, sell the two split contracts to two innovators, one from each non-competitive "industry", reaping multiple gains. Splitting increases the market access of the technology, or reduces excludability in the absolute sense, lowering the risks for the traders. Innovators who win the contracts in a primary market then decide whether to use the contracts for investing or blocking. The contracts are re-tradable, and an innovator can re-sell a contract in a secondary market for what ever reason to another innovator who has the technology to produce products for which the contract is useful. The experimental environment therefore allows the study of how the fixed fee and royalty (f,r) evolve in pricing the linear contract given the investment value and blocking value, legal environment and institution. The systemic gains created by 1) coordination of investment in a quality contract and a trader splitting it, and 2) price signals on value of a certain technology focus, can also be studied, given the legal environment and institution.

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[37] Project Beta refers to the capital asset pricing model in its temoral (CAPM) and inter-temporal (ICAPM) form.

3.3 The institutions

The last components to be defined in the economic system after the economic and legal environments are the primary and secondary market institutions. An important weakness has been that current price theory, patent licensing studies (game theory), and past experiments have been primarily concerned with negotiating one-dimensional contracts under different personal and impersonal market exchange mechanisms like bilateral negotiations and auctions. The theoretical and experimental challenge at hand is to devise and test an institution to trade and price a two-dimensional contract that meets the demands of the risky environment in which inventors and innovators are imbedded.

The auction literature for fixed price auctions was pioneered by Vickrey (1962, Vickrey, 1976), Milgrom and Weber (1982) and others. Since risk neutral agents are generally assumed, a special study of risk averse *buyers* was explored by Maskin (1984). Risk behavior of buyers as a function of levels of capital "cushion" in companies was studied by R. Radner. The finding was that when capital is thinning out, a risk *taking* behavior may replace the otherwise risk adverse behavior observed when capital is sufficient (Radner, 1995). This behavioral issue may be of importance to trading risky patents. Work on linear contracts has been done by Tirole and others but the auction itself is performed in one dimension (Laffont and Tirole, 1987). Patents ("contracts" with the government) have similarities with incomplete contracts since validity is only presumed prior to a challenge in court. Incomplete contracts, without reference to patents, have been studied by Hart and Moore (1988, Hart, 1988) and Tirole (1999). Hart and Moore looked at the renegotiation aspect of such contracts and its relation to the theory of the firm (coordination in a hierarchy).

The literature on "contract bidding" has explored two-dimensional contracts, but only one dimension is typically negotiated here also (Samuelson, 1986, Samuelson, 1987). The other is fixed ahead of time (which can be seen as a kind of separate inter-temporal negotiation). This is equivalent to the seller (or buyer) setting a reservation value on a contract, a feature introduced in one of the auctions in this model. Auctioning off cost-sharing contracts in a theoretical and experimental study, highlighting the moral hazard and adverse selection issues in procurement contracting have been studied by Cox and Isaac (1994). A theoretical model of procurement contracting is developed and tested in laboratory experiments. Market performance is tested for both fixed-price and cost-sharing contracts. Contracts are awarded with first-price sealed-bid or second price sealed-bid auctions. The environment contains post-auction cost uncertainty and opportunity for unmonitored effort in contract cost reduction. They find that cost-sharing contracts reduce procurement expense but also are inefficient because of their induced moral hazard waste and cost overruns. This work, although concerned with the cost saving side have similarities and relevance to issues in the patent trade studied here[38].

With direct relation to patent licensing, Kamien and others have done theoretical work on cost reducing patents (process patents[39]). Kamien has studied patent licensing in a multifaceted way addressing issues of optimal licensing, fees versus royalty in an "either-or-way", private value of a patent and market structure and innovation (Kamien and Schwartz,

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[38] This article was brought to my attention by Prof. David Porter, when discussing the two-dimensional contract for patents and previous literature relating to this problem. However, the article does not address two-dimensional bidding of the linear contract but it provides a complete system of models and experimental test.

[39] In general, in the theoretical analysis that has been done with respect to patents and economics, only marginal process patents have been considered, i.e. the study has in general been done on the marginal value of cost reducing inventions on existing innovations. Here we are interested in product patents (which create value not only lower cost of existing products) and process patents and the systemic effect, or dynamic effect and marginal effect, of patent used in a trade based economic system.

1982, Kamien et al., 1992, Kamien, 1992). His analysis takes the same starting point as Arrow's analysis from 1962, and develops it towards a market structure using auctions and game theory in joint work with Tauman (1986, Kamien and Tauman, 2002). This game theory work is based in part on the work of Aumann. Aumann (2004) addresses the question of the management of risk where the 'folk theorem' in game theory, with discount rates and punishment strategies, seems to work best. A related study was done by Maskin et.al. on repeated games with discounting (compare bidding in auctions), or incomplete information (compare private information) in (Fudenberg and Maskin, 1986). The concept of discounting is directly connected to the cost of capital and management of *financial* risk using the Capital Asset Pricing Model (CAPM) (Sharpe, 1964), in particular in its Intertemporal version, ICAPM (Merton, 1973). The method ties into the investment strategies developed by Markowitz, Miller and Sharpe especially regarding portfolio selection (Markowitz, 1952) and cost of capital (Modigliani and Miller, 1958). To conclude this passage, after a one-dimensional contract is auctioned, the risks remain unchanged as before the auction according to theory. This fact that what happens to the risks is not dealt with in current auction theory was pointed out by Prof. V. Smith during a discussion on spectrum auctions[40]. An importance of the linear contract may be its 'ability' to express and negotiate the risk sharing in the contract which is not done through a single fixed price that simply transfers risk.

The equation to be solved by the economic agents is pricing the two market access values *simultaneously*, one has a more "common value" while the other has a more private value. How the market is organized (the messages and rule set of the institution) is the second independent variable in the experiment[41].

By systematically exploring different messages, information and rules that are commonly used and extensively studied for one-dimensional auction markets both naturally occurring, in game theory and in design markets, the attempt is to broaden some of these institutional designs to study prices, adjustment processes, and gains from trade.

As a first study, different messages are studied for *demand side* bidding together with different bidding rules to investigate which integration of messages and information are needed to efficiently price the tradable linear contract on patents. In this respect, the message format, information it can contain, and rules under which messages are exchanged characterize the second independent variable. Changes in the execution of the competitive demand side bidding are achieved by varying the message bid response a buyer can give to a seller's message ask. The bidding takes place in three way conversation: a buyer can send a simple accept/reject as a response to an ask in fixed fee and royalty, negotiate in royalty as a response to an ask (buyers increase royalty) or negotiate in both fixed and royalty to an ask (buyers can increase bids and sellers can decrease asks in one or both dimensions simultaneously). The sell side has the same message in all institutions, i.e. a fixed fee and royalty. The sell side's Willingness To Accept (WTA) a bid is always public information, whereas information on the demand side's Willingness To Pay (WTP) changes with the institutional rules. See Table I for a summary of messages and information in the studied institutions.

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[40] Ref. to presentation made at the Information Economy Project's speaker series on "Big Ideas about Information" at GMU, May 2, 2006.

[41] Ref. to (Smith 1982) where institutions are made up of messages and rules in an economic analysis. Agents interact with eachother *given* the institutional rules to produce outcomes.

Table I.
Primary market messages and public information

Institution	Seller's ask	Public Information		Buyer's bid
		WTA	WTP	
1	(f↓,r↓)/Accept → (f,r)	(f,r)	←	(f↑,r↑)/Accept
2	(f↑,r↓)/Accept → (f,r)	(-,r)	←	([f↓],r↑)/Accept
3	(f↓,r↓) → (f,r)	(-,-)	←	Accept/Reject

Bidding space: positive and negative values are allowed for (f=fixed fee, r=royalty). Seller starts auctions. Amelioration rules are indicated with ↑ (increase) or ↓ (decrease). Bid=Ask or Accept stops auctions. In institution 2 (f↑) is a de-facto reservation price on [f] asked by the seller.

The first institution is similar to a two-dimensional version of a double-auction except that the seller starts the auction with a first ask. The second institution is a double auction in royalty but with a de-facto reservation value on fixed fee (the sellers can increase and buyers decrease the fixed fee which for all practical purposes means that the seller sets a reservation price on fixed fee). The third institution, a posted offer, is similar to a "manual" Dutch Clock auction with the seller "ticking" down the asking price in two dimensions independently and simultaneously. The third institution is also similar to today's personal exchange mechanisms, where often a seller exclusively (under NDA agreements) goes from buyer to buyer in a sequential order. The effects of this demand side bidding with increasing interactivity in the message and public information exchange can therefore be studied systematically for a primary market [42]. These are thus but three examples of many institutional designs that can be studied in the experimental system. The reason for these three is that they have aspects that are commonly practiced in the real world, and that there have been many experiments run using similar one-dimensional versions (for example (Coppinger et al., 1980, Smith, 1982a, Smith, 1976) (Ketcham et al., 1984, Davis et al., 1990) (Easly and Ledyard, 1979, Friedman, 1984, Friedman and Rust, 1993, Friedman, 1993, McCabe et al., 1992, Rassenti et al., 1982, Rassenti et al., 2002). Thus the two-dimensional market designs both draw from the real world and hopefully will add a new dimension to the auction literature as well.

In the secondary market, contracts can be resold in a fixed price double auction, with the fixed fee and royalty price already determined. This market adds to the dynamics of the system as it allows the initially negotiated contract to be tradable for several periods (simulating the patent life). A contract can still have value to another agent, and can be resold to that agent, if the first buyer finds out that the potential earnings from the contract are higher than the price paid. This "exit" possibility also provides some discipline on a buyer whose intention is to block: getting the contract by simply overbidding on the royalty becomes less sensible. The true investment value would be foregone. The experimental economic system thus allows the study of *dynamic* benefits from the patent system and adds to the literature on *static* benefits.

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[42] This construction also allows to study the price adjustment process, competitiveness of bidding by varying number of buyers and robustness of the institutions by varying the induced values.

4. Informal theory of prices and some initial hypotheses

This section covers an informal discussion on a price theory for the linear contract and some initial hypotheses that will be tested in the experiments using the dynamic model. Let's first go back to the original argument on values. The economic value of an excludable and transferrable patent right was argued in section 2 to be in the competitive-enhancing technology to "manage" the market access risk related to an innovation. Since the right is excluding, it can be used in a new innovation by making investments in the use of the technology, creating a competitive advantage for own products, or blocking others from doing that and thus limiting competition on current own products to protect the current competitive advantage.

Creating new market access, measured in terms of new sales (revenues), is often a long-term strategy involving considerable uncertainty and major capital expenditure. Maintaining current market access, measured in terms of existing revenues, is on the other hand often a short-term strategy involving minimal capital expenditure and much less uncertainty since current sales are known (and can be forecasted with some certainty). By blocking adversaries, market access can temporarily be maintained by a firm, ceteris paribus, and long-term investment decisions can be delayed or "better timed" to the benefit of cash flows from current assets. The proposition for theory is that blocking to maintain sales that could otherwise be irreversibly lost to a more competitive innovations (own or others) is formally similar to an *insurance* contract, where the risk (calculated with some certainty) of irreversible losses are "traded" for a fixed fee. An identical argument is given by Smith (1968) with respect to inventory being an "insurance" against loss of sales[43]. Smith's work expands on an earlier work by Arrow (1965) on optimal protection of assets against casualty or liability loss and is closely followed in the analysis here. The asset that has to be protected here is the market access (customer relations). The decision that has to be made is different: instead of stocking up products, the strategy is to 'blocking' out new competing products. The decision is whether to engage in a 'value negotiation' with customers by using the new technology, blocking the new value and continue to face 'price taking' customers until a better technology comes out or loose ground by not buying the technology. The competitive advantage is ultimately given the excluding right attached to the IP in the product. In the IP case it is the "right" to sell (handed over by the patent right) that provides the "insurance" not the physical availability of the product. These two "insurances" of course work together.

In an insurance contract, a cash payment is paid against the risk of irreversible losses. In the case of the tradable linear contracts on patents, the "insurance" against loss of sales is thus given by the blocking value of that patent right. The proposition here is then that the willingness to pay (WTP) for a patent's blocking value will be expressed in the *fixed* component of the linear contract since this blocking value is the value of "sitting on" the contract and can be owned by any economic agent that could make use of it in an innovation. As with insurance, such risks of loss of market share can are pretty well known. Such a value cannot possibly be expressed in a royalty, when the intention is not to use it (which would yield 0 in payments). If competitive bidding is assumed with discrete incremental but uncertain private values, as is tested in the experiments, then under rational expectations the price would be the average of the probability distribution of possible outcomes[44] of the second

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[43] In Smith 1968, "Optimal Insurance Coverage", p68, Smith states that "the problem of optimal insurance coverage is formally similar to the problem of optimal inventory stockage under uncertainty. To inventory a product is to "insure" against sales loss – the larger the inventory, given the distribution of demand, the greater the 'insurance coverage'."

[44] In the experiment, a uniform distribution is used and the average is therefore the midpoint of the induced value range.

highest blocking value among buyers, plus epsilon. This case also assumes that the same agent has both the highest blocking and investment values. We can now formulate a first hypothesis:

> *H1: The fixed fee that clears the market will be equal to the second highest blocking value among bidders. If traders are involved the fee will equal the highest blocking value among innovators.*

By investing in the technology a firm could potentially increase the competitive advantage of its products and "secure" long-term market access but at the cost of a new and uncertain 'value negotiation' with the customers. The proposed pricing here is looking at such a decision as a project investment using a net present value calculation (NPV) of expected (uncertain) sales, discounted with a "project beta". Due to the inherent uncertainty of such projects, many of these projects may be needed to succeed. If the fixed component reflects a blocking value greater than 0, projects could be accepted up to a royalty where the NPV is still positive *after* the cost of the fixed fee (second highest blocking value) has been subtracted. This makes the royalty payment a buyer is willing to pay linearly dependent on the fixed fee offered. See figure 4 for prediction of prices under rational expectations.
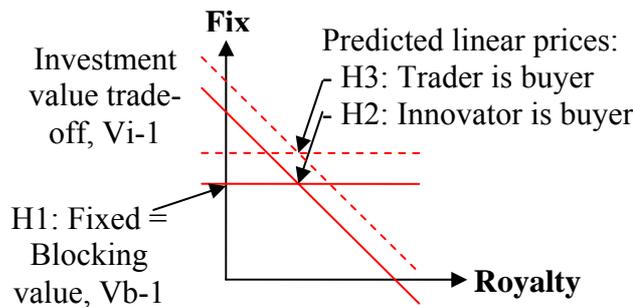
Figure 4. Predicted price in competitive bidding equals the intercept between the blocking value and the investment value linear equations. Prices "above" the lines are unprofitable for their use and "below" profitable for their respective use (invest/ block). The dashed lines are the highest innovator value and the solid lines the second highest value.

We can now formulate a second hypothesis:

> *H2: The predicted royalty price (when innovators are buyers) is then decided by the intercept of the second highest blocking value among agents (since no one would bid higher than that) and consequently the second highest investment value, which is linearly dependent on the fixed fee paid for the blocking value, for an institution that allows simultaneous bidding in both dimensions.*

The third hypotheses is related to the dynamics of trade: If a contract is bought by a trader and split and new contracts are sold for different fields-of-use, the trader would under rational expectations use the risk sharing of the fixed fee (which requires capital) to outbid the innovators through the fixed fee. Some of the gains from trade are therefore shared through the market with the inventor. This would suggest that fixed fees are higher for a contract that is later split. Since traders always would have the incentive to outbid innovators, gains from trade would be equal to the multiplicative value given the increase in fields of use.

> *H3: The fix price would equal the highest blocking value when a trader is the buyer.*

In the case where other induced values are used, for example the highest blocking and investment values are held by different agents, the prices would not be the second highest but in between the second and the highest value depending on the NPV of the blocking and investment values[45].

A fourth hypothesis on systemic risk is formulated: The single-firm 'invent-and-produce' model and two-firm 'invent – produce' model (used in optimal patent licensing studies) are both replaced by the *three*-firm 'invent – trade – produce' model in the designed system. This makes the decision problem dynamic with respect to use of technology and funding for development as the contracts can be split by a trader, potentially multiplying its uses. This may also have effects on the propensity for developing inventions in favor of blocking and lead to a more competitive allocation of capital. In this three-firm trade, capital can thus flow directly into ideas through the contract, independently of the innovation firms, who traditionally fund most of the inventions. (This is a clear trend in many industries, in particular Pharma-BioTech, where bilateral negotiations make this happen through a business model based on a patents.) In the designed system the increase in the competition for technology makes collusion difficult by traditional innovators in the presence of the traders. Instead of investing in stock of an innovator, traders/investors invest in the technology through contracts on patents, split them for different industries/markets/periods and then sell them to potentially more innovators. The economic environment and contract designed may allow for *a* new *role* for capital: to fund trade in new ideas (patent portfolio management companies are today becoming a well-established new business model). This creates a *systemic* change in risk sharing among the three parties *during* patent-time. The injection of capital in this trade to bear risks better in the system (a risk absorption mechanism facilitated by the market) creates the possibility of dynamic gains from trade and competitive decision implemented by this market rather than a hierarchical structure. With the additional trader bidding for contracts, the risk is allocated more efficiently, potentially lowering the systemic risk. Competitive bidding may not only attract capital to trade the ideas, but also to develop them from (for example) the venture capital industry. This suggests that it will not be as easy to block good ideas when they can be competitively priced and gains extracted from potentially multiple innovations. The conclusion here suggest that there is a reduction of cost of capital in the system due to more efficient allocation of risk bearing by the actor with best capability of managing risks given the specialized nature of his firm.

> *H4: A market with transparent prices would lead to a more efficient economic system with respect to use of technology enabled by a more efficient use of capital.*

The last proposition is that the price system itself signals the value of a technology, potentially directing the technology investment focus (technical area) of an inventor to an area of *commercial* interest.

> *H5: More economically useful inventions would be developed when coordination takes place through a market with prices.*

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[45] These cases are not presented here but left for future experiments.

These propositions are contrary to the conclusions of J. Robinson, who in her article "What are the Questions?" (Robinson, 1977), p1337, suggested the problem in the economy to be that the capital to fund new of innovations was accumulated by large corporations and any development decision was at their discretion (emphasis added):

> "Here is the problem. The task of deciding how resources should be allocated is not fulfilled by the market but the great corporations who are in charge of the *finance for development*. These questions involve the whole political and social system of the capitalist world; ..."

Competitive trade in technical knowledge appears to create competition for capital between inventors and innovators, opening for directly funding a market in technology.

5. Summary

In this paper I have proposed a dynamic economic system design for trading patent rights in organized impersonal markets useful for multiple experimental works. An informal theory of pricing a linear contract on the patents has been outlined and initial hypotheses formulated. Two initial experiments have been proposed to study: (i) linear prices and gains from trade, and (ii) coordination of inventive and innovative activities through market prices.
The model allows flexibility in several dimensions for these and future studies, of which these appears the most important contribution towards a more dynamic analysis of the patent system as a trade system:

1. Multiple mechanism designs. Different auction mechanism designs can be tested. The information content of the messages can be varied as well as what private information is accessible publicly through the institution. The adjustment process can be studied to evaluate endogenous bidding strategies. The incentive schemes (of rules) can be studied.
2. A dynamic patent system. Different presumed validities can be used and validity can change over time (between experimental periods). Also information on patent dimensions can be varied by field-of-use, and in-validation of patents can occur in markets and time.
3. The contract can be of exclusive or non-exclusive type. Different number of licenses of the patent can be used in studying prices and coordination. Special types of contracts such as "bundling" of patent rights can be included.
4. The induced values can vary over time. Technology of different lifetimes can be studied. The economic value of a technology varies considerably, from months to decades. The model allows varying values over time to simulate typical technology patterns.
5. The uncertainty in the induced values can vary. This uncertainty can be varied through different value distributions, ranges and averages of the induced values.
6. Additional risk mitigation modes can be varied. Insurance against loss of validity and other "insurable" risks can be included to study effect on prices.
7. The induced values can be varied. Randomizing values of technology allows effective study of n-commodity pricing under rational expectations. Convergence to rational expectations can be studied[46]. Also negative values can be used to study limits of voluntary trade and moral hazards.

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[46] Smith, makes the point that rational expectations with respect to sustainability (Nash) or theory (Muth) can be observed, making it possible to study expectations that are not supported by theory. SMITH, V. L., SUCHANEK, G. L. & WILLIAMS, A. W. (1988) Bubbles, Crashes, and Endogenous Expectations in Experimental Spot Asset Markets. *Econometrica: Journal of the Econometric Society,* 56**,** 1119-1151.

8. The competition environment can be varied. The number of inventors, traders and innovators can be varied to study situations with few and many competitors. This is particularly of interest since there are often a limited number of firms who can use a certain technology.
9. The "technology" environment can be varied. Different "search limitations" can be designed to study coordination between invention, trade and innovation as well as risk taking behavior during the search.

The proposed initial two experiments aim at studying integration of messages, information and institutional rules under varied validity and resulting dynamic[47] prices and gains from trade.

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[47] Since the dynamic system may have different end states (like in dynamic programming) the actual gains could be divided by one or more optimal end states to create a measure capturing some of the dynamic.

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