Fairness in intellectual property valuation and value-sharing:

Towards fair pricing in technology trade and licensing

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ABSTRACT

In today's complex and digital business landscape, innovation is typically not an effort of a lonely genius or an activity confined to a single corporate R&D lab. Instead, the innovation process often involves open innovation, technology trade, and intellectual property (IP) licensing between multiple firms in what is sometimes referred to as an innovation ecosystem. While this interaction is conducive to value creation, it also creates a pressing need for better methods and principles for fairly capturing and sharing value among contributors. The purpose of this paper is to shed light on the plurality and specificity of fairness principles, how they appear in IP negotiation experiments with 105 participants, and what outcomes they generate compared to competitive behavior. The paper especially highlights how investments and the structure of innovation actors, artifacts (such as patents), and activities impact fairness.[1]

1. INTRODUCTION

Competitive behavior in some form is prevalent among all living creatures while fair or just behavior in some sense is a social construction primarily among humans. Competitive behavior is a key subject in economics while fair behavior and justice is a key subject in law. This is not to suggest that legal studies are more human-focused than economic studies, but nevertheless fair behavior does not feature as prominently as competitive behavior in economics, beyond connections between the two such as fair competition. At the same time competition does not feature centrally in legal studies except for competition law. These disciplinary biases in studies of human behavior suggest that competitive behavior and fair behavior are fertile candidates for interdisciplinary studies in law and economics.

One area where there is a central connection between competitiveness and fairness, as well as between economics and law, is that of intellectual property (IP) licensing and technology trade, and the related IP contracting and pricing. In this area, the value of IP is shared between actors through some price mechanism. In commodity markets, sellers are price-takers subject to competition pushing prices down towards marginal costs. IP markets,

in contrast, are characterized by uniqueness of the traded asset and by complementarities between the traded IP and other assets.[2] They are also characterized by low liquidity, low transparency, information asymmetries, intermediation, and two-sidedness (with both buyers and sellers having preferences about each other), typically involving a relatively low number of potential buyers and sellers with unique assets, which can only be valued in connection to their complementary and substitute assets.[3] Consequently, pricing, or in other words value-sharing, becomes a costly and time-consuming negotiation effort, implying considerable transaction costs.

In the current era of digitalization, which is the focus of this journal issue, technologies are becoming increasingly complex, being developed and controlled by numerous actors who collaborate and compete with complementary and substitute assets in innovation ecosystems[4] involving various forms of open innovation.[5] This, in turn, leads to an increasing number of costly transactions of technology and IP.[6] However, research on innovation ecosystems has primarily been occupied with the potential for collaborative value creation in innovation ecosystems[7], leaving a pressing need to better understand how this value could and should be shared among, or fairly captured by, ecosystem actors.[8]

A parallel trend enabled by digitalization is that of smart and automated contracting,[9] which has the potential to offset the increasing transaction costs mentioned above. Some progress has been made in order to standardize and automate contracting, but much remains to be done.[10] For example, there is a need to match automated contract clauses with automated contract prices. Whether it is automated or not, price-setting (including royalty-setting) can be helped by establishing and using a set of *ex ante* agreed upon fairness principles. This kind of axiomatic pricing or "smart pricing" can, at least partly, replace negotiation and thereby decrease transaction costs.[11]

The purpose of this paper is to shed light on the plurality and specificity of fairness principles, how they appear in negotiation experiments, and what outcomes they generate compared to competitive behavior. These fairness principles are of relevance to law in general and to technology trade and IP licensing in particular—not least in complex innovation ecosystems.

The paper will start with a theoretical and conceptual discussion of a number of fairness principles. This is followed by illustrative examples of the differences in outcomes from these and other principles depending on the structure of actors, artifacts, and activities, or in other
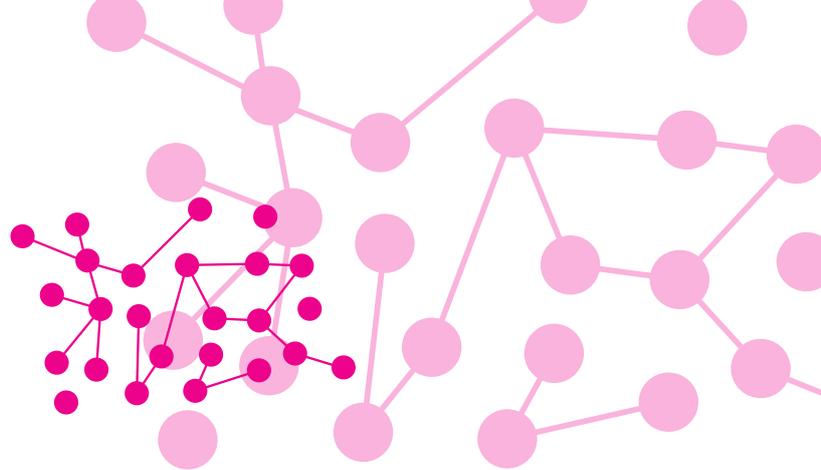
terms depending on the structure of the innovation eco-system.[12] To complement these theoretical principles, the paper then presents empirical results from negotiations in an experimental setting focused on bargaining and fairness of simple IP deals, before finally drawing some conclusions.

As to limitations of this paper, no review of the vast subject of notions and principles of fairness and distributive justice is attempted, nor of problems and methods of experimental economics. The approach in this paper is mainly qualitative and informal although the theoretical underpinnings are possible to formalize and model quantitatively. Moreover, there are both opportunities and challenges with the practical use of fairness principles. One such major challenge is that of incomplete information and information asymmetries across actors. In no

way should this paper be seen as an attempt to downplay such practical challenges, but rather as a small step towards contributing to the theoretical principles leading the way to more practical use.

2. SOME PRINCIPLES AND PROBLEMS OF FAIRNESS

It is fair to say that fairness has a fair deal of connotations. No universal definitional element is apparent, nor is there any universally accepted notion of fairness or unfairness across jurisdictions and cultures. However, a common, if not dominant, notion rests on an egalitarian principle of equity or equality or equal treatment and equal sharing of something across players in a fair game with rules that are reasonable and do not discriminate against any of the

1   The work on this article has been undertaken within the projects "Intellectual property management in digitalizing businesses" and "Intellectual assets, innovation, growth and value creation and the role of new digital technologies and digital property" at Chalmers University of Technology and Institute for Management of Innovation and Technology, respectively. The highly capable research assistance by Justin Lundgren, and the financial support from VINNOVA (grants 2016-04666 and 2017-04469) are gratefully acknowledged. Authors in alphabetical order.

2   David J. Teece, "Profiting from Technological Innovation: Implications for Integration, Collaboration, Licensing and Public Policy", Research Policy 15, no. 6 (1986); Ove Granstrand, The Economics and Management of Intellectual Property: Towards Intellectual Capitalism (Cheltenham: Edward Elgar Publishing, 1999).

3   Mark A Lemley and Nathan Myhrvold, "How to Make a Patent Market", Hofstra Law Review 36, no. 2 (2007); Ove Granstrand, "Towards a Theory of Innovation Governance and the Role of Iprs", GRUR International 69, no. 4 (2020).

4   Ron Adner and Rahul Kapoor, "Innovation Ecosystems and the Pace of Substitution: Re-Examining Technology S-Curves", Strategic Management Journal 37, no. 4 (2016).

5   Henry W. Chesbrough, Open Innovation: The New Imperative for Creating and Profiting from Technology (Boston, MA: Harvard Business School Press, 2003); Granstrand, "Towards a Theory of Innovation Governance

and the Role of Iprs."; Marcus Holgersson and Sarah van Santen, "The Business of Intellectual Property: A Literature Review of Ip Management Research", Stockholm Intellectual Property Law Review 1, no. 1 (2018).

6   David Andersson and Fredrik Tell, "The Market for Patents in Sweden: Past and Present", Stockholm Intellectual Property Law Review 1, no. 2 (2018) Ove Granstrand, Evolving Properties of Intellectual Capitalism: Patents and Innovations for Growth and Welfare (Cheltenham: Edward Elgar Publishing, 2018); Marcus Holgersson, Ove Granstrand, and Marcel Bogers, "The Evolution of Intellectual Property Strategy in Innovation Ecosystems: Uncovering Complementary and Substitute Appropriability Regimes", Long Range Planning 51, no. 2 (2018); David J. Teece, "Profiting from Innovation in the Digital Economy: Standards, Complementary Assets, and Business Models in the Wireless World", Research Policy 47, no. 8 (2018).

7   Leonardo Augusto de Vasconcelos Gomes et al., "Unpacking the Innovation Ecosystem Construct: Evolution, Gaps and Trends", Technological Forecasting and Social Change 136 (2018); Ron Adner and Rahul Kapoor, "Value Creation in Innovation Ecosystems: How the Structure of Technological Interdependence Affects Firm Performance in New Technology Generations", Strategic Management Journal 31, no. 3 (2010).

8   Ove Granstrand and Marcus Holgersson, "Innovation Ecosystems: A Conceptual Review and a New Definition", Technovation

90-91, no. February-March (2020).

9   Daniel M Hoyt, Robin M Lee, and Alan L Lickiss, "Automated Contract Negotiator/Generation System and Method", (Google Patents, 2000); K. Christidis and M. Devetsikiotis, "Blockchains and Smart Contracts for the Internet of Things", IEEE Access 4 (2016). ; Skye Fletcher and Frank Tietze, "Automating licensing payments for connected devices – A techno-economic analysis of DLT based systems", in F. Urmetzer (Ed.) "Blockchain: a managerial perspective for industry" (Springer, Forthcoming).

10 Charlotta Kronblad and Johanna E. Pregmark, "Beyond Digital Inventions—Diffusion of Technology and Organizational Capabilities to Change", in Legal Tech, Smart Contracts and Blockchain, ed. Marcelo Corrales, Mark Fenwick, and Helena Haapio (Singapore: Springer Singapore, 2019).

11 In the telecommunications industry there have been efforts focused on capping aggregate royalty rates of standard essential patent to enable fair, reasonable and non-discriminatory (FRAND) licensing. See, e.g., G. Brismark and K. Alfalahi, "Patent Strategies - a Fork in the Road toward 4g", Ericsson Business Review 2008, no. 3 (2008); Holgersson, Granstrand, and Bogers, "The Evolution of Intellectual Property Strategy in Innovation Ecosystems: Uncovering Complementary and Substitute Appropriability Regimes."

12 Granstrand and Holgersson, "Innovation Ecosystems: A Conceptual Review and a New Definition."
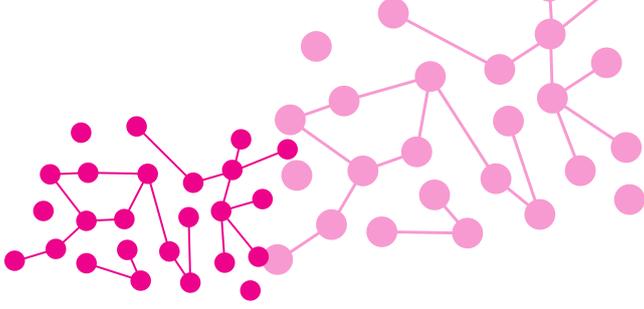
players. Such a principle may be sufficient for acceptance of fairness but it might not be necessary, as the popularity of playing roulette against the odds indicates. Equality in sharing might on the other hand be necessary but not sufficient as the problems with equality in cake cutting or pie sharing among several (more than three) kids indicate due to procedural uncertainties, envy, and disputes. As to serious games in bargaining about IP rights, a serious search for applicable and acceptable fairness principles is warranted to reduce transaction costs (apart from being warranted on moral grounds or on pure utilitarian grounds).

The search for acceptable fairness principles in general can be guided by stipulating a set of desirable properties they ideally should have, such as being:

- Egalitarian or equitable in the sense that something is equalized across some relevant entities like individuals or groups of them and there is no discrimination
- Efficient in the sense that the outcomes are Pareto-optimal (i.e. there is no other outcome that is at least as good for all and better for some)
- Envy-free in the sense that nobody thinks someone else is better off (and if so willing to trade)
- Guilt-free in the sense that nobody feels guilty about the outcome
- Robust against manipulation, strategic gaming, and misrepresentation
- Transparent

The ideal fairness principle does not exist, however, so choices and trade-offs between these desirable properties have to be made, typically between equity and efficiency.

An egalitarian principle in itself is moreover far from unproblematic. Apart from the basic problems of conceptualizing equality or equity and compromising between equity and efficiency, problems arise regarding, for example, who, what, when and how to equalize—i.e., problems in answering the questions:

- **Who are the subjects or actors to be equalized?**
- Individuals, teams, or organizations?
- Owners, producers, users, or third parties?
- **What objects, resources, artifacts, or outcomes are to be equalized?**
- Levels of or changes in gross or net absolute or relative returns, profits, costs, or terminal wealth?
- Some other measure of value, expected value, or discounted value?
- Some other entity altogether, like a piece of cake or a piece of background or foreground knowledge or access to opportunities?
- **Which activities are carried out in order to equalize?**
- Sharing, allocating, redistributing, repaying, encumbering, transferring values or valuables?

- **When is equality in treatment and/or outcomes to be established?**
- *Ex ante* or *ex post* in the short or long term?
- **How is fairness to be established and by whom?**
- By yardsticks, rules, or cultural norms applied by participants, third parties, or some judicial institution?

Answers to these (mostly old philosophical) questions generate a number of fairness principles, or, alternatively, means to reduce some measure of unfairness, in some cases related to principles of justice, e.g.:

- **A proportionality principle**
- As when awarded IP damages are proportional to the number of infringed and valid patents (without concern about their structural importance)
- **A probabilistic principle**
- As when players are given an equal chance to something or an equal expected value or utility of something (without concern for envy *ex post*)
- **A reciprocity principle**
- As expressed by Jesus: "whatever you desire for men to do to you, you shall also do to them"[13] (without concern for differing preferences or values among people)
- **A Marxian principle for distributive justice**
- As expressed by Marx: "from each according to his ability, to each according to his need"[14]
- **A Rawlsian principle for distributive justice**
- As when conditionally providing most to those with the dearest need plus providing equal opportunity to all[15]

These examples are listed here in order to contextualize the following discussion rather than to attempt a brief review of the rich literature from ancient times onwards on various notions of fairness, justice, equality, right, reason, etc. As these notions are deeply embedded in our culture(s) they tend to enter into negotiations, often implicitly, which calls for some explication. This is so especially when axiomatic bargaining approaches are sought for, i.e., principles that bargaining parties can make binding commitments to *ex ante*, e.g., in form of fair, reasonable and non-discriminatory (FRAND) commitments in royalty-setting of IP licenses.

This paper focuses on egalitarian fairness principles involving some form of proportionality or reciprocity. Such principles in a bargaining context could simply be classified as cost-based, value-based, or investment-based, depending upon what is being shared and equalized.

From an investment point of view, equalizing the rates of return (on investment) could be motivated as fair and reasonable since capital constrained investors tend to rank their indivisible investment opportunities according to rate of return rather than according to absolute returns from investments. Thus, this would ensure fair rates of return (FROR) in relative terms. This approach has been proposed for FRAND-based royalty-setting for independent assets in form of non-exclusive patent licenses with additive returns and investments among the licensees.[16] On the other hand if the investments have already been made with sunk costs and the corresponding assets are pooled *ex post* as complementary assets in a joint

collaborative project with economies of scope it might be considered a more fair approach to equalize absolute returns, since bygones are bygones. Thus, this would ensure fair returns (FR) in absolute terms.

Finally, as to limitations of these two fairness principles, one may observe that neither of them provides portfolio value shares that are preserved under aggregation and disaggregation of assets or asset-holding players. This is most easily seen from considering the example with two asset holders, each with one left shoe, and a third asset holder with one right shoe. The left shoe holders could pool their assets and then capture half of the portfolio value as their fair share jointly and then split this half equally among themselves, thereby each getting a quarter.

In case of patents instead of shoes, this example could be reformulated to correspond to the situation when two strongly complementary patents A and B are held separately and a third party holds a strong substitute patent C to B. Note that C as well as B are complements to A, see Figure 1.
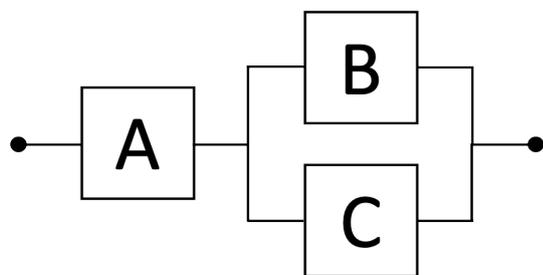

Figure 1 Patent A with complement patents B and C, which in turn are substitutes to each other.

Now suppose B is invented in R&D stage I and then B is invented around by C at a subsequent R&D stage II. Essentiality of B now is lost. Then the previous fair 50/50 split between A and B is no longer fair considering the portfolio {A, B, C}. If instead applying the so called Shapley value[17], introduced in 1951 by Lloyd Shapley who later received the Nobel Prize[18], the value shares of A, B, and C in stage II are 2/3, 1/6, and 1/6. This is also a type of coalitional outcome. Here, the value is split in accordance of each patent's weighted average marginal contribution to the coalition. It is not clear that this split would be considered fair and reasonable to the B-holder, who then would have no incentive to allow the C-holder to enter into any collaboration, while the A-holder has a strong incentive to do so. Thus, a Shapley-based fairness principle could produce non-Pareto changes in the value sharing of a dynamically changing asset portfolio, in which new pure substitute patents are included. At the same time it could be argued on other fairness grounds that the new entrant, i.e., the C-holder, does not add total value to the portfolio, just redistributes the Shapley value, and thus should not receive any value. One could also argue that the B- and C-holder could form a coalition, pool their substitute assets and claim a fair share for their coalition, and then split that share equally. The A-holder, on the other hand, has a strong incentive to abandon a fair sharing regardless of any fairness principle, since pure competitive bargaining could allow the A-holder to appropriate almost the total value.

This illustrates a number of things:

- There are several equally justifiable fairness principles among which a choice has to be made
- Complementary as well as substitute assets matter for appropriation and sharing of value
- What is fair and reasonable may depend upon how the assets are created over time[19]
- Fairness could be exercised among assets, among partitions (modules) of assets and among actors with differing outcomes
- Fairness could be exercised sequentially

The next section further elaborates on this with numerical examples as illustration, and then also considers how investments may affect fair sharing and pricing.

[13] Matthew 7:12, The World English Bible.

[14] Karl Marx, Critique of the Gotha Program (1875).

[15] John Rawls, "A Theory of Justice", (1971).

[16] Ove Granstrand and Marcus Holgersson, "The 25% Rule Revisited and a New Investment-Based Method for Determining Frand Licensing Royalties", LES Nouvelles 25 (2012).

[17] The Shapley value is a general egalitarian method for valuation of contributions from players in a cooperative game or contributions from assets in a portfolio without any concern about the initial wealth of the players. The method is based on reciprocity in the sense that the marginal value any player contributes to any other player's share of any coalition's value in a cooperative game is bilaterally equalized. The fair value of any player then turns out in a somewhat surprising and counterintuitive way to become a weighted sum of that player's marginal value added to each conceivable coalition in the game with the weights being the average over all coalition sizes of the average marginal value added by that player to each coalition of a certain size. This is more easily grasped by a formula; see, e.g., Kevin Leyton-Brown and Yoav Shoham, "Essentials of Game Theory: A Concise Multidisciplinary Introduction", Synthesis lectures on artificial intelligence and machine learning 2, no. 1 (2008). For further applications of the Shapley value in patent portfolio valuations, see Ove Granstrand, "Valuation and Value Sharing of Structured Portfolios with Complementary and Substitute Assets", CIM Working Paper 2014:1, Chalmers University of Technology (2014).

[18] Formally The Sveriges Riksbank Prize in Economic Sciences in Memory of Alfred Nobel.

[19] This is also discussed by Coase in the classical case of an upstream factory polluting water for a downstream laundry. This is generally considered unfair to the laundry but would it be unfair if the factory was first established and then the laundry was located downstream despite knowledge about the pollution? In general there is a presumption of a first mover advantage in rights allocation. See Ronald H. Coase, "The Problem of Social Cost", Journal of Law and Economics 3, no. Oct. (1960).

3. ILLUSTRATIVE EXAMPLES OF SIMPLE FAIRNESS PRINCIPLES AND BARGAINING SITUATIONS

To illustrate the conceptual discussion above and the potential outcomes of different fairness principles a couple of simple numerical examples will be introduced. First assume two patents, A and B, owned by two different firms. A is worth 50 alone, while B is worthless on its own. Jointly, however, the two patents are worth 100. What is then a fair split of the joint 100 between the A-holder and the B-holder? According to experience from discussing these issues with practitioners and students over several years, there is close to a consensus that a fair split of the 100 would be 75 to the A-holder and 25 to the B-holder. The argument typically brought forward is that the individual value of A (50) should be kept by the A-holder, while the added value of combining A and B (another 50) should be distributed equally (25 each) between the A-holder and B-holder since they contribute equally.

By adding a third patent, C, and a third actor, the C-holder, things are made more complicated. Now assume that A, B, and C are all worth zero on their own. The combinations {A, B}, {A, C}, {A, B, C} are all equally valuable, being jointly worth 100 (see Figure 1). This means that B and C are substitutes while they are both complementary to A, in line with the discussion in the previous section. While this is still a relatively simple example, there no longer is consensus what a fair split of the value of 100 between A, B, and C is. One way of arguing is that since there is competition between the B-holder and the C-holder, the A-holder has the opportunity to play one off against the other and reap very close to all of the value while the others would not receive anything or hardly anything. Another way of arguing is that the B-holder and the C-holder can form a coalition through which they would reach the same bargaining power as the A-holder. Then A would be valued at 50 and the portfolio of B and C would be valued at 50, which would then be split up equally (25 each) between B and C. This is the structural proportionality principle. A third way of arguing is that whenever it is decided which one of the two patents B or C is used in conjunction with A, that one is equally important as A, and they should therefore be valued equally (50 each). This is the selective proportionality principle.[20] A fourth way of arguing, here called pure proportionality, is a variant of the previous, but instead of assuming a patent selection among substitutes it assumes equal value of all complementary and substitute patents (in this case 33 each). A fifth way of arguing is to calculate the Shapley value, as briefly introduced above, leading to A being valued at 67 and B and C each at 17. The outcomes of these different fairness principles are summarized in Table 1.

The example above can also illustrate how the structure of actors, technological artifacts (inventions, patents, etc.), and activities in an innovation ecosystem impact the perception of fairness. First, consider actor structure, and compare the standard situation introduced above in Figure 1 with a situation where patent A and B are owned by Owner 1 while C is owned by Owner 2, see Figure 2a. Since Owner 1 holds both of the two necessary complements, i.e., the complete technology, while Owner 2 just holds an incomplete technology, with zero value on its own, most would argue that it is not fair that Owner 1 should share any value with Owner 2, and that Owner 1's two patents therefore are equally valuable. This is in line with the selective proportionality principle, see Table 1. Second, consider artifact structure. By focusing on symmetries among artifacts one outcome is that patents B and C are together equally important and valuable as patent A, and that B is equally important and valuable as C, see Figure 2b. This is the structural proportionality principle. An alternative is to calculate the weighted average marginal contributions in line with the Shapley value. With the Shapley principle B and C are also equally valuable, but with a lower joint value than A. Third, consider activity structure, and more specifically the order in which the assets or artifacts are created. Assume that patent A and B are invented in stage I and patent C in stage II, see Figure 2c. There is then a first mover claim to fairness in the sense that who is first to invent has arguably a larger fair claim than who is second with an invent-around substitute patent, and the selective proportionality principle could again be applied.

Table 1. Illustrative outcomes from different fairness principles compared to competitive bargaining (with rounded numbers).

	A	B	C	Total
Competitive bargaining	100-ε	ε or 0	0 or ε	100
Structural proportionality	50	25	25	100
Selective proportionality	50	50 or 0	0 or 50	100
Pure proportionality	33	33	33	100
Shapley value	67	17	17	100

a)

□ Owner 1
■ Owner 2
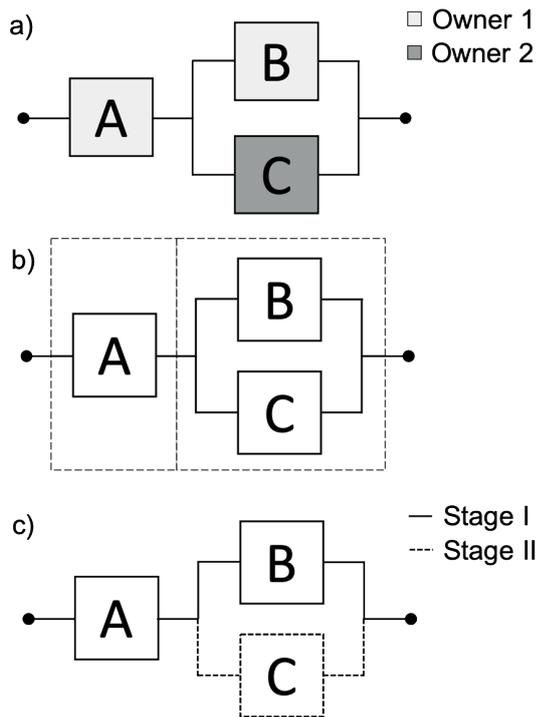
b)

c)

— Stage I
--- Stage II

Figure 2 Three patents and the related actor, artifact, and activity structures.

In addition to the complication of a third patent as discussed above, the investments behind each of the three patents can now be introduced to complicate matters further. Assume that the A-holder has spent 30 on developing A and the holders of B, and C have spent 10 each on their patents.[21] This means that the net value or surplus of the three patents is 100 – 30 – 10 – 10 = 50. The same relationships apply, meaning that each patent is worthless alone but A together with B and/or C have a gross value of 100. Fairness can now be argued on the basis of absolute values (some form of fair returns) or relative values (some form of fair rates of returns) when accounting for investments.

For principles based on absolute values, emphasizing fair returns, the actors involved in collaboration are first reimbursed for their investments, and the surplus value is subsequently shared in line with the different principles introduced above. For example, in line with structural proportionality of surplus, the (explicit or implicit) coalition between the B-holder and the C-holder receives reimbursement for its investments (10 + 10 = 20) plus half of the surplus (50 / 2 = 25), meaning a total gross value of 45, which is shared between the B-holder and the C-holder. Analogously, the A-holder receives reimbursement of its investment (30) plus half of the surplus (25), meaning a total gross value of 55. The selective proportionality, pure proportionality, and Shapley principles follow the same logic of being applied to the surplus rather than gross value, see Table 2.[22]

Table 2 Illustrative outcomes from different fairness principles when accounting for investments (with rounded numbers)				
	A	B	C	Total
Amount of investment	30	10	10	50
Principles based on absolute values / fair returns (FR):				
Structural proportionality of surplus				
gross value	55	23	23	100
net value	25	13	13	50
Selective proportionality of surplus				
gross value	60	40 or 0	0 or 40	100
net value	30	30 or -10	-10 or 30	50
Pure proportionality of surplus				
gross value	47	27	27	100
net value	17	17	17	50
Shapley distribution of surplus				
gross value	63	18	18	100
net value	33	8	8	50
Principles based on relative values / Fair rates of returns (FROR):				
Selective fair rate of return (FROR)				
gross value	75	25 or 0	0 or 25	100
net value	45	15 or -10	-10 or 15	50
Structural FROR				
gross value	60	20	20	100
net value	30	10	10	50

However, another way to argue in case of bilateral contracting or various coalitions is that since the A-holder invested more it makes sense that A should be assigned a higher share of the net value. Such principles would be based on relative values, and they follow the logic of sharing profits or dividends across investors or shareholders. The more you have invested, the more you should receive. Applying this logic in case of a bilateral contract involving A and B, it would be fair if A and B are assigned values leading to equal rates of returns, as discussed above.[23] If the A-holder receives 75, the rate of return is (75 – 30) / 30 = 150%, which leaves 25 to B-holder, also giving a rate of return (25 – 10) / 10 = 150%. If instead the B-holder and C-holder form a coalition that contracts with the A-holder, one fairness principle is that the coalition's rate of return should be the same as the A-holder's rate of return. This would lead to the final value distribution in Table 2, i.e., 60 to the A-holder and 20 each to the B- and C-holder.

4. AN EXPERIMENT OF BARGAINING AND FAIRNESS IN PATENT TRADE

After introducing a number of theoretical fairness principles, and illustrating the variation of outcomes they produce, results from an experiment of bargaining and fairness in patent trade will now be presented to explore how individuals bargain and reason about fairness in collaborative and competitive situations. In the first section below the experimental design is briefly introduced, and in the second section the experimental results are presented.

4.1 Experimental design

The experiment was conducted through oTree which is an open source platform for behavioral research.[24] A cohort consisting of 105 university students took part in the experiment as participants in bargaining games. The participants were kept physically separated from each other and communicated through game-internal chat messages on their computers. They were kept anonymous and were asked not to reveal their identities in the chat. In order to create incentives for the participants to perform well, real world prizes of 1000 SEK were given out in a lottery, and lottery tickets were awarded to the participants in a weighted fashion based on performance. The experiment was part of a larger study on the game theoretic aspects of intellectual asset negotiations and only the parts relevant for this paper are presented here.

The first part of the experiment to be presented here was a trilateral game which featured three anonymous players who were assigned the roles A-holder (buyer), B-holder (seller) and C-holder (seller). The A-holder held a product patent zero value, the B-holder held a process patent B with zero value and the C-holder held a process patent C with zero value. The total value of holding both the product patent and one of the process patents, i.e., either A and B or A and C, was however 100. Thus, A formed a complementary relation with B and C respectively, while B and C formed a substitute relation with each other, i.e., the same structure as in Figure 1 which has

been introduced conceptually and numerically above.

During three rounds, the A-holder negotiated with the B-holder and/or the C-holder for the complementary process patent. The players communicated by chat to agree on a, for all players, non-binding price. At the end of each round the buying A-holder was asked to give a take-it-or-leave-it binding offer to the selling player, which the seller could choose to accept or reject. I.e., the end of each round was designed as a version of the classical ultimatum game. The ultimatum game has many variants but in its basic standard form it has one proposer, who proposes as a take-it-or-leave-it offer a split of 100 to a responder who can accept the offer in which case the split is paid out to the players, or reject the offer in which case neither player gets anything. Rational players who prefer something to nothing without caring about fairness are then expected to end up with a 99/1 split. Empirically, however, an aversion to unfairness almost always enters into the game as well as sometimes a preference for fairness. Thus, fairness has an intrinsic value and the responder is willing to pay a price for it, depending on a variety of factors, according to empirical studies.[25]

In the first round, only the A-holder and the B-holder got to negotiate while the C-holder was asked to wait. Similarly, in the second round the B-holder was instead asked to wait while the A-holder and the C-holder got to negotiate. In the third round the A-holder could negotiate with both sellers simultaneously, and could at the end of the round choose to give an offer to either one of the selling players. For all three rounds, the B-holder and the C-holder had no knowledge of each other unless the A-holder, who held this as private information, chose to reveal it.

In an additional round of the trilateral game all three players were asked to discuss retrospectively what would have been a fair split of the total value of 100. At the end of the round, the A-holder would enter the fair value assigned to each player and the other players would enter whether they agreed with these specified value assignments. The intention was here to explore the participants' sense of fairness rather than the bargaining outcome.

The second part of the experiment was a public goods game[26] which featured four players in which two were given an initial wealth of 100,000 SEK (categorized as "poor") and two were given an initial wealth of 2,000,000 SEK (categorized as "rich"). All players could choose what amount to contribute to a common investment pool, which was to be multiplied by 1.6 after which all four players shared the final sum in four equally large parts. See Figure 3 for an illustration. The players had information about whether they were a poor or a rich player, but they did not know the initial wealth assigned to the other player category. They were asked to maximize their individual terminal wealth, which would be the individual share of the return from their joint investment plus the share of the individual initial wealth they did not invest.

Similarly to the trilateral game there was an additional round of the public goods game. In this round the players discussed what would have been a fair principle to use for the distribution of the total returns.
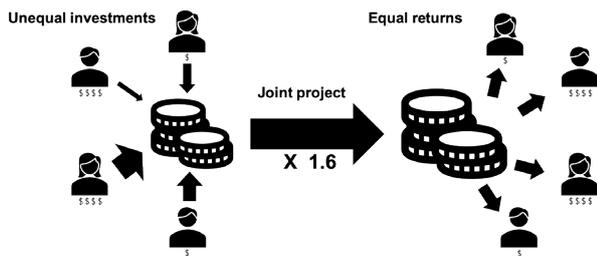
Figure 3 The public goods game with two rich and two poor players investing in a common pool.

4.2 Empirical results from experiment

The results from the three negotiation rounds of the trilateral game are presented in Table 3, where the number of deals made, the proportion of games where a deal was made, as well as the sample mean, sample median, and sample standard deviation of the accepted prices are presented for each round. Player groups with apparent misinterpretations of the game or frivolous behavior were deemed as outliers and these data points were excluded when computing the summary statistics. Four (11%) out of the 35 games played in total were excluded for these reasons.

The data seems to suggest a trend with decreasing prices over the number of rounds. To assess whether these diffe-

rences are statistically significant, two-sided Wilcoxon signed-rank tests were performed for differences between round one and two and between round two and three, respectively.[27] The test of the difference between round one and two gave a p-value of 0.0143 and the test of the difference between round two and three gave a p-value of 0.0005. Thus, both of the differences are significant at the 0.05 significance level, meaning that the data indicates a decreasing trend in price over consecutive rounds. This decrease is in line with expectations given the competition on the seller side of the market and the information asymmetry in favor of the A-holder, even though the absolute numbers are surprisingly high.

As for the fairness discussion round of the trilateral game, there were 23 participant group discussions left to analyze after excluding outliers. Out of these, 14 (61%) managed to agree upon a fair value distribution. A majority consisting of nine of the groups that reached an agreement (64%) proposed a 33/33/33 split, corresponding to the pure proportionality principle. Two groups (14%) agreed to a split of 50/25/25 which corresponds to the structural proportionality principle. Another two groups (14%) suggested something in between, namely a 40/30/30 split where the buyer takes a larger share. One group with agreement (7%) proposed a 60/0/40 split. The A-holder of the groups that did not agree proposed the following value distributions: 33/33/33, 50/25/25, 40/30/30, 50/50/0, 50/0/50 and 60/40/0. These results are summarized in Table 4.

Table 4 Suggested fairness distributions in the trilateral game

Value distribution			# of proposals	
A-holder	B-holder	C-holder	With agreement	Without agreement
33	33	33	9	2
50	25	25	2	2
40	30	30	2	1
60	0	40	1	0
60	40	0	0	1
50	50	0	0	2
50	0	50	0	1
Total			14	9

Table 3 Results and summary statistics from the trilateral game

	# of deals	Proportion of deals	Sample mean	Sample median	Sample standard deviation
Round One	24	0.77	48.5	50	3.7
Round Two	21	0.68	45.4	47	6.2
Round Three	29	0.94	41.1	40	9.1

[23] This approach has been introduced as the investment-based method of royalty calculation, see Granstrand and Holgersson, "The 25% Rule Revisited and a New Investment-Based Method for Determining Brand Licensing Royalties."; Ove Granstrand, "Fair and Reasonable Royalty Rate Determination", les Nouvelles 41, no. 3 (2006).

[24] For details, see Daniel L. Chen, Martin Schonger, and Chris Wickens, "Otree—an Open-Source Platform for Laboratory, Online, and Field Experiments", Journal of Behavioral and Experimental Finance 9 (2016).

[25] For example, the price goes up if the responder is under the influence of alcohol,

meaning that alcohol increases the unfairness aversion or in other words the propensity to become "pissed off" by an unfair offer. For more details, see Carey K. Morewedge, Tamar Krishnamurti, and Dan Ariely, "Focused on Fairness: Alcohol Intoxication Increases the Costly Rejection of Inequitable Rewards", Journal of Experimental Social Psychology 50 (2014).

[26] See J. H. Kagel and A. E. Roth, eds., The handbook of experimental economics (Princeton University Press, Princeton, 1995).

[27] Wilcoxon's non-parametric test was chosen over Student's t-test as the sample means could not confidently be assumed to follow a

normal distribution and the equal variance assumption is seemingly violated. Furthermore, the paired two-sample signed-rank test was chosen to take advantage of the dependent structure coming from the same participants playing together in all rounds. It came at a cost of reduced sample size however, as only data points where there was a deal in both rounds could be included in the test. This consideration resulted in 18 data points being included in the first test and 19 data points being included in the second test.

The results from the first round of the public goods game are presented in Table 5, computed from the 27 games that were played. As can be seen in the table, the investments from rich players are considerably higher than those of the poor players. In relative terms however, poor players made larger contributions to the common pool, indicating a higher relative contribution among the poor, albeit with smaller absolute contributions. The relative difference is not significant however, according to a two-sided Wilcoxon rank-sum test performed on normalized values with significance level 0.05, which produced a p-value of 0.079.[28] Furthermore, no significant differences between males and females were found.[29]

Of main interest to this article is the fairness discussion round of the public goods game, which was focused on agreeing upon a fair distribution of the returns from the game. The results were summarized by manually analyzing and concluding the overall consensus from the chat messages. Most participants agreed that splitting the return by equal rate of return (or FROR) would be fair. Out of all 27 groups, 19 (70%) either agreed fully or had a majority suggesting that this would be the fairest way of sharing the returns. Four groups suggested or agreed to equal absolute returns (more in line with the proportionality principle discussed above). There were additionally a number of more creative suggestions, examples being receiving the amount invested plus an equal absolute share of the profit, FROR given that everyone invests 100,000 SEK and a split of 45% of returns to the rich players and 5% of returns to the poor players. All of these were unique when compared across groups.

Table 5 Results and summary statistics from the public goods game

	Poor group (n = 54)	Rich group (n = 51)[30]
Average size of investment	45,012	614,525
Average size of investment as share of initial wealth	0.450	0.307
Median size of investment	50,000	500,000
Median size of investment as share of initial wealth	0.5	0.25
Standard deviation of size of investment	37,436	587,437
Coefficient of variation for size of investment	0.83	0.96

5. CONCLUDING DISCUSSION

Trade and transfer of new technologies, data, and information is growing fast worldwide, due to increasing technological complexity and R&D costs, and not the least due to new digital technologies, which are facilitating trade and transfer processes through lowering transaction costs. At the same time digital technologies are traded and transferred as information products and thus take on dual roles in trade and transfer. Transaction costs could also be lowered by managerial and legal means for improving market search, negotiations, contracting, dispute resolution (arbitration, mediation, litigation), and by provision of a contractual infrastructure such as the IPR system. This paper has attempted to argue that employment of notions and principles of fairness and fair pricing behavior of technology and IP licenses in the spirit of axiomatic bargaining is one way to lower transaction costs compared to competitive pricing due to the idiosyncrasies of technology and IP markets. Fairness principles may moreover be implemented in automated contracting through algorithms, certified as fair analogous to the certification of fair trade. The use of fairness principles may also convey other benefits such as increased equity but also costs such as decreased efficiency. However, fairness is an ambiguous concept, witnessed not the least by experiences from FRAND licensing in the telecommunications innovation ecosystem. The purpose of this paper has been to shed light on the plurality and specificity of fairness principles, how they appear in negotiation experiments and what bargaining outcomes they generate compared to competitive behavior.

One contribution of the paper is the highlighting of how focusing on actor, artifact, and activity structures, respectively, impact fairness. Since these components are central components in innovation ecosystems[31] the results here indicate the close relationship between the architecture of an innovation ecosystem and the fair value distribution, or fair value capture, among the ecosystem participants. This is a promising avenue for future research, not least since research on innovation ecosystems has primarily been concerned with value creation.[32]

Another contribution of the paper, more specifically from the experiment, is that the employment of some amount of fairness in bargaining is quite frequent even in

[28] A non-parametric Wilcoxon test is once again chosen as assumptions regarding normal distribution and equal variance cannot be made. This time the samples are independent however, requiring a rank-sum test as opposed to the signed-rank test used previously.

[29] For more research on inequality and contributions to public goods, see Lisa R. Anderson, Jennifer M. Mellor, and Jeffrey Milyo, "Inequality and Public Good Provision: An Experimental Analysis", The Journal of Socio-Economics 37, no. 3 (2008).

[30] Note the difference in sample size which is due to the number of participants not adding up to a multiple of 4.

[31] Granstrand and Holgersson, "Innovation Ecosystems: A Conceptual Review and a New Definition."

[32] Gomes et al., "Unpacking the Innovation Ecosystem Construct: Evolution, Gaps and Trends."; Granstrand and Holgersson, "Innovation Ecosystems: A Conceptual Review and a New Definition."

[33] This goes in line with the rich research on ultimatum games. See, e.g., Martin A. Nowak, Karen M. Page, and Karl Sigmund, "Fairness Versus Reason in the Ultimatum Game", Science 289, no. 5485 (2000).

competitive settings.[33] When the actors then are instructed to strike a fair deal, a number of different fairness principles appear with or without concern for the structural importance of the different patents for sale or the structural importance of the different patent rights holders. A surprising finding is the propensity to use the pure proportionality principle even in the experimental setting involving both complement and substitute patents, i.e., disregarding the uniqueness of patent A.

However, when investment information is provided, a majority of participants converge towards fairness principles based on relative value, striving towards equal or fair rates of return (FROR). The FROR principle in turn could be used in at least two ways as illustrated by the examples, either through equalizing rate of returns simultaneously or sequentially. A sequential or stepwise FROR principle first considers coalitions or modules of actors or artifacts with similar structural positions, i.e., B and C in the examples, and then equalize the rate of return with regard to the coalitions' aggregate investments, and, second, makes a fair sharing within the coalitions. In other and more general words, one first performs an inter-group sharing and then an intra-group sharing, possibly using different fairness principles as well.

The Shapley value, that takes structural importance but not explicitly investments into account, was never invoked in the experiment, possibly due to bounded rationality and lack of awareness, but could analytically be used also when investments enter the picture as demonstrated conceptually.

It is interesting to note how the inclusion of investments, sacrifices, or efforts more generally apparently changes our notions or perceptions of fairness. A practical implication of this observation is that one should devise principles for output sharing that takes investments, efforts, or sacrifices into account in order to incentivize input contributions for a common good. On a more general level this observation opens up questions for further research and philosophical speculation about the role of entitlements or endowments in the conception of fairness and distributive justice. One can also note that principles for fair sharing of value also could apply to fair sharing of chores and even in some situations a "fair" or justifiable sharing of damages and guilt, such as in a crime committed by several actors or a disaster caused by the joint failure of several artifacts. Again, many questions for further research open up.

A final conclusion is that the concept of fairness is difficult even in simple cases like here. This hardly comes as a surprise to practitioners and scholars of law, but maybe more so to managers and executives of technology-based firms and corporations, where there is an increasing strive to build and engage in innovation ecosystems and other forms of open innovation and collaborative R&D. This points to the great potential impact from formulating, analyzing, and testing fairness principles. Hopefully, this article has not only started to contribute with such principles, but also inspired others to participate in the fair deal of research on fairness that lies ahead.
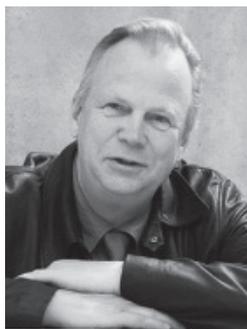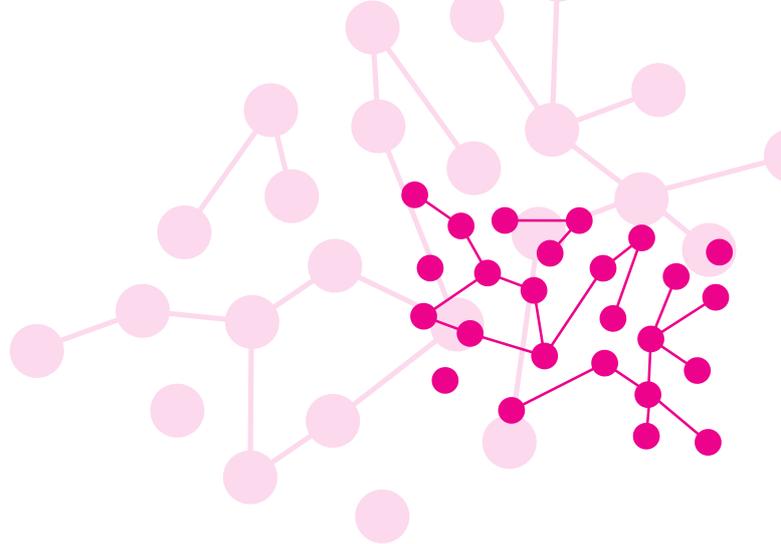
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