Understanding the System Dynamics of the University-Industry Technology Transfer Process and the Potential for Adverse Policy Creep

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***Abstract*--Numerous investigators have explored the growth and value of the technology transfer process from universities to industry. Regional and national organizations have extolled the virtues of technology transfer and the growth in technology entrepreneurship has been touted as a major contributor to regional economic development. The characteristics and structure of technology transfer organizations and processes has been discussed in literature, but from a policy perspective the effects of technology transfer policy decisions have not been modeled for their impact. This paper provides a systems dynamics approach to modeling the technology transfer process, tuned using data from the Association of University Technology Managers (AUTM) annual report. The systems dynamics model shows that a pure internal focus of a technology transfer office policy on short term licensing revenue maximization via tough licensing terms will result in a suboptimal revenue position for the university, and that a relaxation of these terms actually leads to a more optimal returns position for the university. This has broad impacts on the technology transfer process, and suggests further modeling scenarios that may introduce secondary dynamics.**

I. INTRODUCTION

Universities are increasingly expected to take on technology transfer and commercialization as a part of their mission [1]. Carlsson and Fridh [2] point out the importance of technology transfer programs to the academic institutions' mission of education, research, and public service because they provide "a mechanism for important research results to be transferred to the public, service to faculty and inventors in dealing with industry arrangements and technology transfer issues, a method to facilitate and encourage additional industrial research support, and a source of unrestricted funds for additional research" among others. The core elements in university–industry relationships are transactions that occur through the mechanisms of sponsored research support (including participation and sponsorship of research centers), agreements to license university intellectual property, the hiring of research students, and new start-up firms [3]. Licensing has traditionally been the most popular option, but universities and their TTOs are increasingly also taking into consideration the entrepreneurial dimension of technology transfer. Equity from startups can yield a payoff in the long-term, whereas licensing and sponsored research create a constant revenue stream, depending on the specific licensing terms [4].

Since the Bayh-Dole Act, more and more universities have founded technology transfer offices (henceforth, TTOs) and created corresponding structures [5]. With regard to technology licensing, TTOs have several contract options, such as exclusive and non-exclusive licenses or options, and materials transfer agreement as well as different reward options for the university and the inventor, such as royalties, equity, and barters [6]. The majority of university scientist need to maintain their academic routines, and they are more likely to rely on the assistance from TTOs in filing patent applications, evaluating the financial potential, the marketing and negotiation of their intellectual property (henceforth, IP) [6, 7]. The existing literature has focused on different aspects of the licensing process as well as the terms and forms of licensing contracts in particular [8-11]. This paper aims to fill the gap by providing a system dynamics approach for evaluating the effects of technology transfer policy decisions. We will focus on the technology licensing process and look at the impact of different strategies from a policy perspective. By using data from the Association of University Technology Managers [12] and existing literature mentioned above, this will allow us to investigate these effects with regard to time.

II. BACKGROUND

A. Stakeholders in the University-Industry Technology Transfer

There are three key stakeholders in the UITT process, independent from licensing a technology or creating a startup. The first stakeholder is the inventor, usually a university scientist, who made a scientific discovery or developed a new process [13]. Academic scientists, especially those who have not received tenure yet, are under a lot of pressure to publish their ideas and inventions. In most cases, and usually based on the tenure policies of the university, they publish in certain research journals or give presentations at leading conferences. They strive for peer recognition and an increasing network in academia [14]. The second stakeholder is the TTO, which manages the university's IP portfolio, looks out for potential companies and entrepreneurs, and negotiates the technology transfer deals [15]. Although TTO staff wants to get the university's IP off the shelf and generate revenue, they "do not want to be accused of 'giving away' lucrative taxpayer-funded technologies or […] to safeguard the 'researchers and the research environment' that generates innovations" [14]. This may sometimes delay the commercialization process, even though Baldini [16] and Markman, et al. [17] describe that the faster university TTOs can commercialize their patents, the greater the revenues and the more startups they create.

Finally, the third stakeholder is the established company or the entrepreneur, who wants to commercialize the university-based technology [13, 18]. Especially when knowledge and innovation is a key factor for their businesses to succeed, entrepreneurs and firms want to keep proprietary control over their IP and typically try to secure exclusive rights. Siegel, et al. [14] also found that speed really matters for firms and entrepreneurs, because they often want to be the ‘first-mover’ and take advantage of the non-existence of competitors.

B. The University-Industry Technology Licensing Process

The general university-industry technology licensing process steps are invention disclosure, patent awarded, license negotiated, and payback to the university according to the license agreement [2, 18-21]. The revenue generated from licensing activities is typically identified as one of most important outputs of the UITT process. In terms of the UITT, licenses are “the legal rights to use a specific piece of university intellectual property” [3]. The existing literature basically agrees on the main process steps of the UITT process in general or respectively the university-industry technology licensing process in particular. Except for some variances regarding the names and the addition of one or two additional steps, all process models contain the following basic steps: invention disclosure, patent issued, license sold, revenue generated [2, 19, 21, 22]. These authors do in a comparable manner also agree on the general inputs (invention disclosures and employees at the university TTO) and the outputs (number of licenses sold and the generated licensing income) of the UITT process. Carlsson and Fridh [2] state that, as a rule of thumb, “only half of the invention disclosures result in patent applications; half of the applications result in patents; only a third of patents are licensed, and only a handful (10 – 20%) of licenses yield substantial income”. Thursby and Thursby [23] state that embryonic technologies, those which are in a very early stage in its development process, are more likely to fail, because additional R&D and time is required and these technologies might not fit the need anticipated at the time when the license agreement is signed. Among others, this is one of the reasons, why some firms are not likely to license a technology from a university.

C. Impact of Licensing Terms

In terms of licensing agreements and their impact, there is one very important question to be answered at the beginning: who is better informed of the value of an innovation, the firm or the university? It is obvious that the answer usually depends on whether we are talking about the market opportunities or the potential value of a certain technology. With regard to the market demands and the commercialization opportunities, firms are usually better informed, which gives them the opportunity to lower the licensing fees by underestimating the potential to the university. In fact, universities are typically not as well informed about market demands, and hence, they face an adverse selection problem. In this case, the licensee may claim that a patent has a low commercial value to obtain a low fee [11]. If the university is better informed than the firm as to the value of the innovation, it can use royalties to signal the value of the innovation [9, 24]. To sum it up, a fixed payment means that the TTO receives its money up front, independently of the firm's revenues, while under a variable payment contract, such as royalties, the revenues for the university depend on the firm’s performance and the success of a technology. Royalties link the TTO's profits to the value of the innovation, and thus, their inclusion signals a high-quality innovation [3, 11]. In this way, combining fixed and variable payments is one way of risk sharing between the two parties [8].

Bray and Lee [25] report that license issue fees typically range from $10,000 to $50,000 but may be as high as $250,000 while royalty rates are typically 2–5%, but may be as high as 15%. Especially for medical or biotech technologies, the royalty rate may even reach 30%. Early payments to the university and the inventor, including up-front fees, as well as annual fees that make it costly for a firm to keep a technology may be necessary to make sure that the licensee signs the contract with the intention of using the technology. This may prevent situations in which the firm wants to license an invention with the only objective of shelving it in case of success; for example, it may want to prevent competitors from accessing the technology [11]. It is also interesting that, based on a survey by Thursby, et al. [26], 31% of their respondents had never been able to negotiate an agreement that used only an up-front fee. In general, it can be stated that an optimal licensing agreement has to balance the incentive effects of royalties or milestones for both the firm and the university scientist [11].

D. Licensing Reputation

Eight out of ten managers or entrepreneurs found that universities are too aggressive in exercising their IP rights, which results in a hard line during the licensing negotiations, probably because they are concerned about not realizing sufficient revenue [22]. A reason for this might be the fact that TTO staff and faculty members have unrealistic expectations with regard to the value of their technologies. But Siegel, et al. [18] also found out that only 13.3% of the TTO directors and administrators think that they are too aggressive. Similar differences in the perception of the TTO performance can be found with regard to the bureaucracy and inflexibility of university administrators (80% of managers and entrepreneurs; 6.7% of TTO directors and administrators) and poor marketing, technical and/or negotiation skills of TTOs (55% of managers and entrepreneurs; 13.3% of TTO directors and administrators).

These discrepancies lead to the notion that there such a thing as a licensing reputation. Reputation itself is a multidimensional construct [27]. With regard to Figure 1, the licensing reputation is a product of the goodness of licensing terms from the firm's perspective, the support from the TTO and university scientists, especially after the license agreement is signed, the readiness of the technology, basic/applied research ratio of the university, and the R&D reputation of the university. But with regard to the reputation and its correlation to the goodness of licensing terms, there are different approaches.

Macho-Stadler, et al. [28] developed a reputation model, which basically says that a TTO might want to shelve some patents, and thus raising the potential buyer's beliefs of expected quality, which results in fewer but more valuable inventions being sold at higher prices. This would lead to a higher efficiency from a financial point of view.

Another reason might be the risk aversion of universities and TTOs. This can be frustrating for entrepreneurs or managers, who are willing to license technologies. Some schools have adopted very conservative negotiation stances and prefer to maximize the financial return to the university, even if this significantly reduces the likelihood of licensing the technology at all [18].

E. Pool of Firms

Thursby and Thursby [29] surveyed 1,385 business units from the mailing list of the Licensing Executive Society, Inc., U.S.A. and Canada (LES) in the fall and winter of 1998-99. This number already excludes businesses that do not license-in technology from any source or who do not sponsor university research, as well as firms that went out of business. They received 300 respondents, and of these, 112 indicated they had licensed-in university technologies from U.S. universities over the period 1993-97, and 188 indicated that all of their licenses were from other sources, though 55 of the latter had sponsored research at U.S. universities during that period.

In addition to the barriers to the university-industry technology transfer identified by Siegel, et al. [22], Thursby and Thursby [29] found that 45.7% of 106 respondents that had licensed-in from U.S. universities rank personal contacts between their R&D staff and university personnel as extremely important. Furthermore, 9.3% of 98 respondents indicated that it is extremely important to them that their licensing staff routinely canvass universities for new technologies.

So we can conclude that there are three kinds of firms: Firms that are licensing from universities (P_d), firms that are willing or interested in licensing in general (P_w), regardless if they are currently licensing or not, and the total number of firms in the U.S. (P_t), which includes the prior mentioned two pools. The relationship between the above mentioned pools is $P_d<P_w<P_t$. Especially the latter finding by Thursby and Thursby [29] shows that a university can increase the pool of firms P_w, which are interested in licensing-in technologies from that particular university.

III. HYPOTHESIS

Established companies and entrepreneurs would directly benefit from a less aggressive TTO during the negotiation. But, firms are more likely to license if they have prior experience, which means that it might be helpful for the university to license more technologies and create a pool of firms that are willing and more like to cooperate again. In the majority of cases, technology was transferred not through formal search, but through some prior relationships among individuals [30]. Siegel, et al. [18] recommend, based on their findings, that universities and TTOs should adopt a more flexible stance in negotiating technology transfer agreements and streamline UITT policies and procedures. As a result, we formulate the following hypothesis for the course of this paper:

H1. A less aggressive licensing strategy and hence the relaxation of the licensing terms leads to a greater overall return to the university in the long run.

There is a sweet spot between simply trying to get as much patents licensed as possible, which includes giving away some of them for free or at a low charge, and trying to get as much money as possible from every single deal, and very high upfront payments in particular. We expect this sweet spot in a more industry-friendly are compared to the status quo.

IV. METHODOLOGY

A. System Dynamics

System Dynamics is an interdisciplinary approach to understand complex, dynamic systems [31]. It is one of the equation-based modeling techniques, as opposed to agent-based modeling, which encapsulate the behaviors of individuals, the so-called agents [32]. System Dynamics is designed to help managers and policy makers dealing with changing environments and complex information feedback structures. Two ways can be used to illustrate systems: stock and flow and causal loop diagrams [31].

To test our hypothesis, the independent variable in our system dynamics simulation is the *goodness of licensing terms*. This variable reflects not only the royalty rate, but also the flexibility and bureaucracy of the TTO and thus the ease of doing business from the firm's perspective. We define this variable to range from 0 (hard terms, charge firms everything upfront, no flexibility) to 1 (easy terms, university gives away IP for free). Jelinek and Markham [33] described five different IP ownership arrangement and their relevance to both the industry and universities. These range from IP that results from collaborative research with universities are owned by industry (1), via industry owns IP, but allows the university to continue research and publish (2), university owns IP, but it allows exclusive licenses to industry for any use (3), university owns IP, but it allows industry to an exclusive license for a narrow field of use (4), to university owns IP, but it makes it available non-exclusively to any company that wants it (5).

These arrangements are reverse to our definition, meaning that (1) relates to 1 on our scale and (5) to 0. Even though (1) does not directly mean giving all the IP away for free, it underlines the need for the university to consider other commercialization channels and not only licensing, which results in more flexible technology transfer policies. On the other hand, (5) meaning that it is very unattractive for companies to license. Most university policies are located between (3) and (4), making 0.375 the current baseline. We will eventually develop three different models based on three baselines 0.25 (a), 0.375 (b), and 0.5 (c) to cover the uncertainty about the exact baseline.

With our system dynamics model, we are looking at a ten-year time span in daily steps, thus ranging time t from 0 to 3650. We do not take into consideration leap years. The ten-year period is chosen because it is the half-life of a patent and the assumption that all licenses pay royalties for ten years.

There may also be variances among different circumstances such as the nature of the technology, the readiness of the technology, the industrial sector that the firm or the entrepreneur works or respectively wants to work in, or geographical issues. However, we will develop a general model because from a systems perspective, modeling these differences is too complex to eventually still being able to handle the system. A university is also not able to plan the development of disruptive or breakthrough technologies, so it has to prepare for selling *standard* technologies.

V. THE UNIVERSITY-INDUSTRY TECHNOLOGY LICENSING PROCESS

The first two models illustrate the internal view that most TTO directors and administrators have, which focuses only on direct licensing revenues (see Figure 1 and Figure 2). They start with the *R&D budget α* and end with the *Licensing Returns RET* as the main output. If formulas are different due to the three baselines, they are indicated with (a) for β_1, (b) for β_2, and (c) for β_3, accordingly.

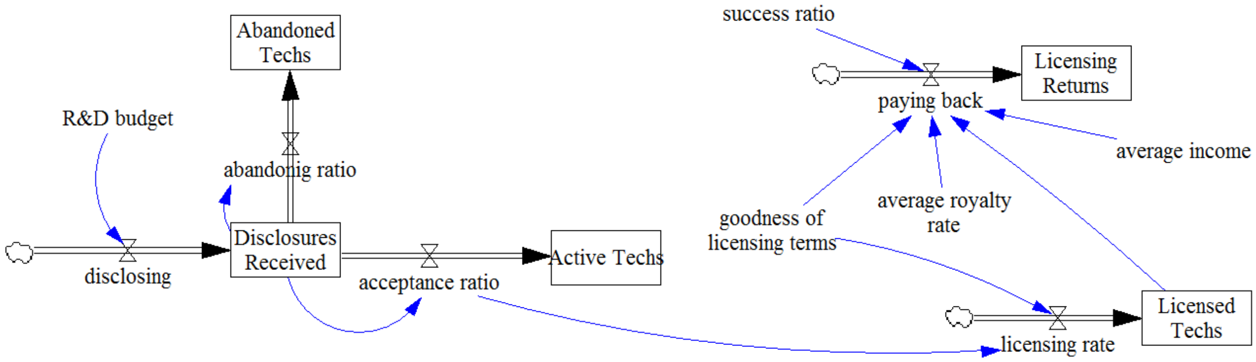

Figure 1. System dynamics model of internal perspective of technology licensing by TTOs

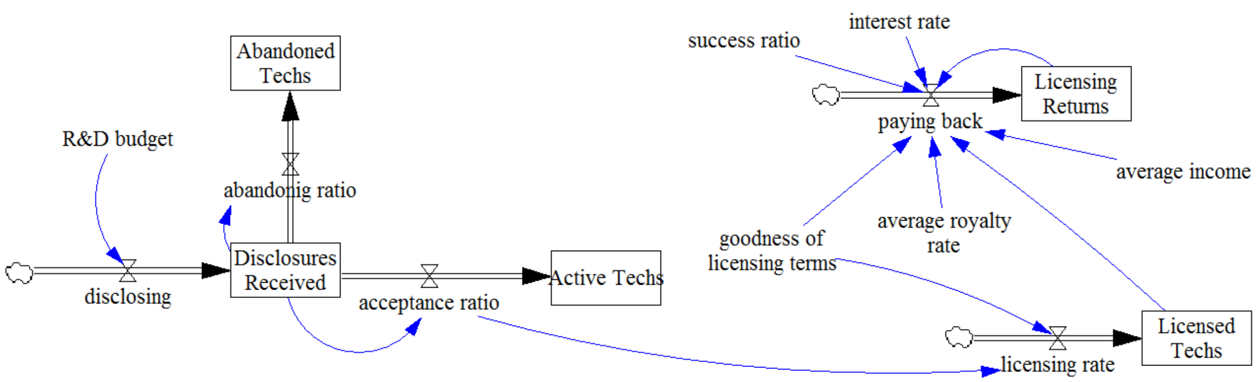

Figure 2. System dynamics model of internal perspective of technology licensing by TTOs with compound interest

The *R&D budget α* is a constant variable set as 1 in all our models. The data from the AUTM licensing survey was used to tune the model. Based on a ten-year average from 2002 to 2011, one disclosure costs 1.040% of the total R&D budget for the average university [12]. On the same ten-year basis, we calculated that the ratio of disclosures received and patent application filed as 58.59%, which equals the acceptance ratio. The stock Disclosure Received is defined as the integral of one inflow and two outflows over time.

$$DR = \int D\text{-}ABR\text{-}ACR\ dt \qquad (1)$$

The two stocks *Abandoned Techs* and *Active Techs* are by the same pattern simply the integrals of their inflows. *Active Techs* represents at any point in time the current number of patent applications that a university has filed.

$$ABT = \int ABR\ dt \qquad (2)$$

$$ACT = \int ACR\ dt \qquad (3)$$

The *licensing rate* rages from 0 to 1, depending on the *goodness of licensing terms*. The ten-year average ratio of new patent application filed and licenses, based on the Association of University Technology Managers [12] licensing survey, is 47.241%. This licensing rate was used for each of the three baselines to then calculate the exponent. We needed to use the *acceptance ratio* for the *licensing rate* instead of the stock *Active Techs* because the tuning data was only available annually and not based on the total amount of patents that universities were holding. The stock Licensed Techs represents the number of licensing agreements the university has signed with companies. At this point, there is no outflow to this stock. We assume that all licenses executed stay active for at least the ten years we are looking at.

$$LT = \int LR\ dt \qquad (4)$$

The *success rate* is 44.32%, based on the 10-year AUTM average and calculated by dividing licenses yielding income by the cumulative number of active licenses. The ten-year *average income* per day is $425 per license [12]. We assumed an *average royalty rate* of 5%. For the calculation of the impact of the *goodness of licensing terms*, we set the baseline in each case to 5% royalty and defined that if the *goodness of licensing terms* is 0, the royalty is 100%. In case the goodness is 1, the royalty rate is 0%. The stock *Licensing Returns* displays the cumulative payback of the licenses that have been executed.

$$RET = \int PB\ dt \qquad (5)$$

The difference between the two models lies in the *paying back* flow. We set the *interest rate*, the cost at which a university is able to borough money, to $\tau=5\%$. From an external perspective, the *licensing* represents the fact that universities are able to increase P_w, the number of firms that are interested in licensing-in technologies and willing to cooperate with a particular university, as the reputation increases (Figure 4).

When Siegel, et al. [22] surveyed about the barriers to the university-industry technology transfer in their survey, 80.0% of the managers and entrepreneurs indicated that the university is too aggressive in exercising its intellectual property rights, but only 13.3% of the TTO directors and administrators think so. This underlines a huge discrepancy in the perception of the performance of a TTO, a ratio of approximately 6, and leas to the exploration of the structure of the relationship with the pool of firms.

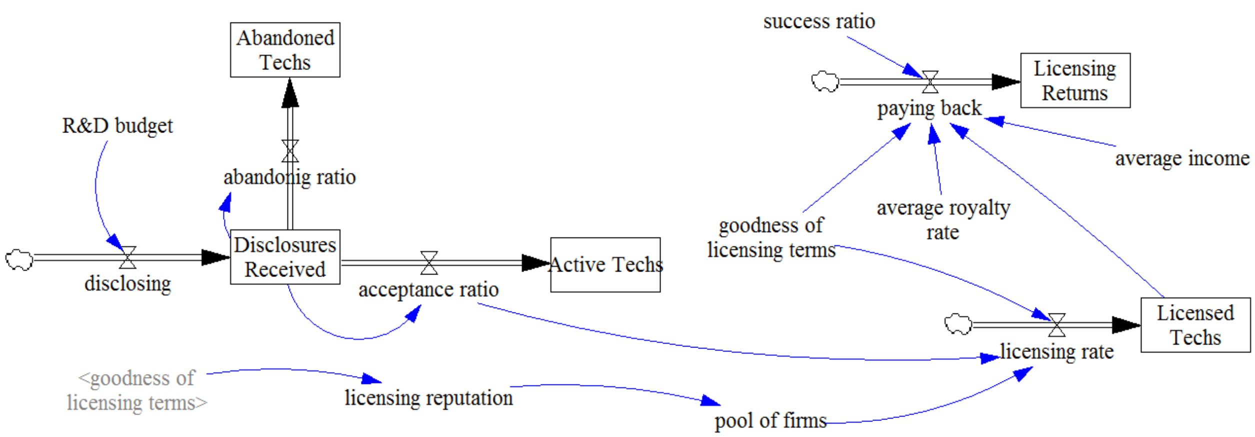

Figure 3. System dynamics model of external perspective including reputation and pool of firms

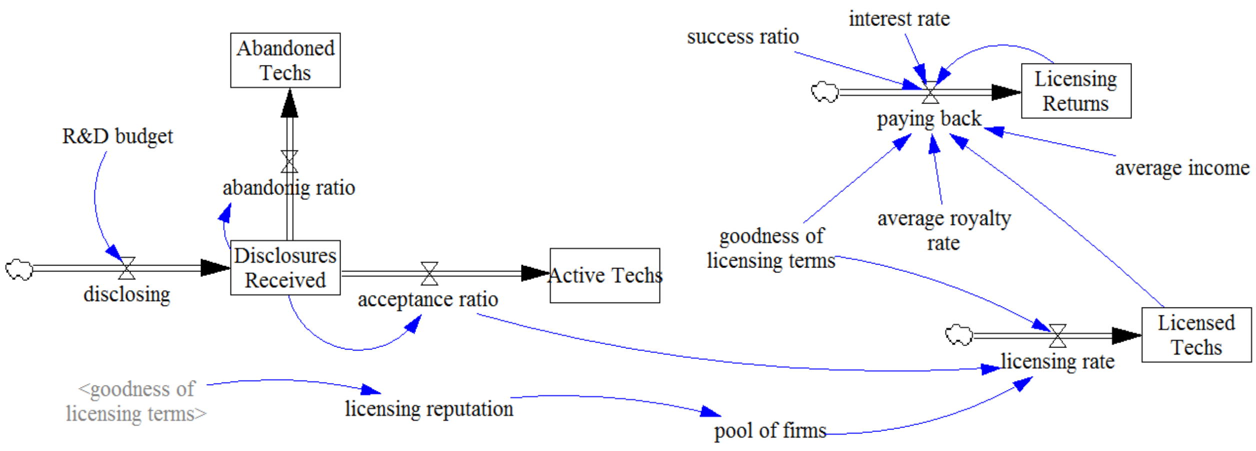

Figure 4. System dynamics model of external perspective including reputation, pool of firms, and compound interest

VI. RESULTS

The results with these models provide insight to the licensing process, especially in terms of policies for optimizing the returns. The internal perspective defined in the model in Figure 1 yields a slightly higher maximum return if the policy shifts towards tougher licensing terms. This shift holds for the compound interest version of the model in Figure 2, yielding a higher maximum value tan the non-compounded version.

By including the external perspective of licensing reputation on the firms participating in the licensing pool, the results show a shift in the opposite direction. In this case the optimal return to the university occurs with licensing terms that are more favorable to the company than under baseline conditions. Furthermore, the use of a policy consistent with the first model analysis, following tougher licensing terms, would yield a return significantly lower than achieved by relaxing the licensing terms. In all cases the return curves are parabolic, concave downwards, and the maximum value is below the internal only model, suggesting the internal only model over-estimates the potential returns to the university. Our PICMET presentation will present a detailed overview of the numerical results.

VII. DISCUSSION

If a university TTO has only the internal view (strategy 1) and disregards the effects caused by the licensing reputation, our hypothesis would be judged as false. The internal view model shows that ougher licensing terms, which results in a smaller amount of executed licenses, result in a greater total revenue after ten years. However, as with many systems dynamics models, external forces play a key role in how the system behaves. When we include the licensing reputation balancing loop in the systems dynamics model and the pool of firms that are willing to work with the university (external view, strategy 2), we recognized a shift of the maximum to the right-hand side, meaning it is better to relax the licensing terms. This means, if a university actually uses strategy 1, the perception is to increase revenue by about 3% (for all baselines, without compound interest). But it disregards the decrease of the pool of firms caused by its decreasing reputation. This fact results in total revenues of only about 83% compared to the baseline and 20% less than expected by the university based on its strategy.

If a university decides to relax its licensing terms with the goal to licensing more, the risk of making less money than expected is lower. By including the time value of money, we observed greater overall returns for each model due to compound interest, but it did not shift the maximums in any direction on the x-axis, simply shifted them upwards. The curves became steeper around the maximum, but the maximum was achieved exactly at the same goodness of licensing terms point than without the compound interest.

It may be stated that, by only considering technology licensing, universities are not far away from the calculated maximums, it is just the strategy that may have to be changed to avoid future disappointments. However, a better licensing reputation will also increase the attractiveness of the university and thus the willingness of companies to participate in collaborative research (an potential additional reinforcing driver of return on university IP). It is also more like that if company made a great deal, it donates money to the university (another potential additional reinforcing driver of return on university IP). In addition, there is a potential impact of goodness of terms on the success rate. Small companies and start-ups and their R&D and marketing ability will be affected negatively by very high upfront cost or royalty rates. The trends that we observed to the tougher licensing terms (without the effect of the licensing reputation on the pool of firms) on the one hand and to more relaxed licensing term (when including the licensing reputation and the pool of firms) on the other hand, will be further amplified by including a feedback from licensing returns to R&D budget and thus increasing the number of scientific discoveries. The model that we present in this paper is only the lower bound, the bias and the resulting smaller licensing revenues by not considering the external view will be even greater the closer we get to a more comprehensive model.

VIII. CONCLUSION AND SUGGESTIONS FOR FURTHER RESEARCH

Looking at current trends in university technology licensing processes, university TTOs have to alter their technology transfer policies if they wish to increase returns to universities. If they only focus on their revenues and do not consider their licensing reputation and the fact that they are able to increase the pool of firms that are willing to cooperate, they have the potential to earn lowers returns. They need to consider the big picture of the system in which they operate. The work presented in this paper is only the beginning of a more comprehensive system dynamics model (see Figure 11 for a causal-loop diagram). In the future we will consider additional reinforcing loops for collaborative research (R3) and philanthropy (R4). Collaborative research (or sometimes referred to as sponsored research) is a key metric of research-intensive universities. Especially for the university scientist, this has advantages over licensing or donations. First, all the money goes directly into the research budget. And second, the scientist gets the money upfront or subsequent payments to conduct the research and does not solely depend on other funding. TTOs and their performance are often evaluated by looking at the revenue they generate for the university. But often funding through sponsored research is not recognized as revenues, so the TTO does not always get credit for its work in arranging and negotiating these deals.

Companies are more willing to donate money back to the university after a great deal, from their point of view, rather than if they feel they have been exploited and overcharged by the university and did not get the support that they may have needed after making the deal. The factors affecting the willingness of donating money are almost the same as those affecting the licensing reputation of the university. Existing literature does not provide any evidence about this phenomenon with regard to the willingness of to donate based on the TTO performance or reputation.

We need to conduct empirical research on these issues, because the data available is not sufficient to create these loops. In addition, empirical research has to be done on the licensing reputation concept, factors influencing the reputation, and the balancing loop B1. We assume that if the licensing reputation is increasing, so are corporate expectations, making it harder for the university to meet these expectations with its terms and services due to saturation effects.

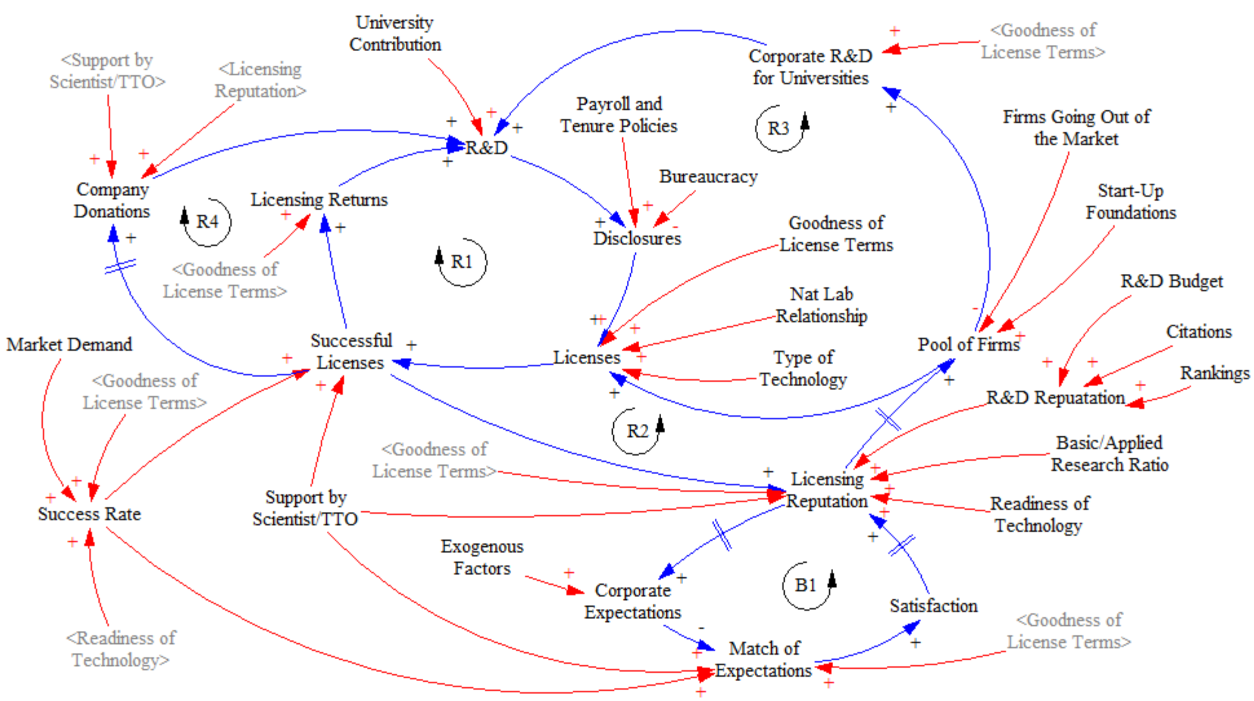

Figure 11. Holistic view on the UITT system

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