Grantbacks, Territorial Restraints, and Innovation[5]

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Abstract

We analyse the effect of grantback clauses in licensing contracts. While competition authorities fear that grantback clauses might decrease the licensee's *ex post* incentives to innovate, a standard defence is that grantback clauses are required for the patent-owner to agree to license its technology in the first place. We examine the validity of this "but for" defence and the equilibrium effect of grantback clauses on the innovation incentives of the licensee for both non-severable and severable innovations, which roughly correspond to infringing and non-infringing innovations. We show that grantback clauses do not increase the patent-holder's incentives to license when non-severable innovations are at stake but they do when severable innovations are concerned – suggesting that the "but for" defence might be valid for severable innovations but not for non-severable ones, in direct contradiction to regulation in some jurisdictions. Moreover we show that, for severable innovations, grantback clauses can increase the range of parameters for which follow-on innovation by the licensee occurs. Our work extends the large literature on sequential innovation to an environment where information diffuses through licensing rather than through the mere act of patenting. In this different informational set up we show that Green and Scotchmer (1995)'s conclusion that the initial innovator should have a patent of infinite breadth no longer holds.

Key words: licensing ; innovation; grantback; patent

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1. Introduction

Studies of the prevalence of licensing suggest that when local expertise matters or barriers to trade are significant, it is common for patent-holders to license their technology to a local firm and earn revenues from royalty payments rather than attempt direct entry[9]. While the monetary significance of this activity is difficult to pin down, Zuniga and Guellec (2009) find that, in a recent survey of the European Union (EU) and Japan, 20% of firms in Europe and 27% in Japan grant licenses to non-affiliated entities. The Organisation for Economic Cooperation and Development (OECD, 2015b and 2015c) finds that international trade in knowledge assets in 2013 for 32 OECD countries was, on average, 2% to 3% of GDP or a total of $364707.7M for receipts and payments[10].

Such licensing is generally seen as welfare increasing because it ensures that local production is done efficiently and that technology diffuses across markets and firms. Indeed, such efficiencies underpin the argument for the pro-competitive potential of licensing agreements found in European, US and Japanese policy and regulatory documents[11].

On the other hand, these authorities recognise that certain contract clauses can diminish licensing's social value. For example, the treatment of improvements to the licensed technology, and in particular whether improvements made by licensees must be "granted back" to the licensor "may reduce a licensee's incentives to engage in research and development and thereby limit rivalry." (FTC, 2016)[12]

The policy landscape for grantbacks has not crystalised into a single dominant approach. Despite misgivings about their effect on innovation incentives, the landmark *Transwrap* case[13] in the US established that grantbacks were not *per se* illegal. Recent proposed US guidelines echo this by stating

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[9] There is a large literature on entry mode in international trade. Markusen and Xie (2014) and the special issue that it is a part of summarises many of the main features of this literature.

[10] This figure measures "cross-border, disembodied trade in technology….Licensing to reproduce/distribute computer software and audio-visual products are excluded." For details, see OECD (2015b, 2015c).

[11] See EU (2014) paragraph 17, Japan Fair Trade Commission (2007), and FTC (2016) for statements of the pro-competitive potential of licensing, extracted and detailed in our working paper Ambashi et al (2016).

[12] See also EU Technology Transfer Guidelines at paragraph 132, EU (2014); Japan Federal Trade Commission (2007) at 4.4.viii(c) and 4.4.ix(b) and Ning, Gong and Li (2016) who state, "The negative effects of grant-backs on innovation and competition are therefore the focus of China's legislation".

[13] See Schmalbeck (1975) for detailed discussion.

that, "[a] non-exclusive grantback …may be necessary to ensure that the licensor is not prevented from effectively competing because it is denied access to improvements developed with the aid of its own technology" (FTC, 2016). A decidedly more negative view can be found in the 2008 Anti-Monopoly Law of the People's Republic of China, which argues that grantbacks are likely "[to be] injurious to proper functioning of normal competition" despite the procompetitive effects of "reducing licensing risks for licensors and…facilitating innovation". (Ning, Gong, and Li, 2016). Indeed the National Development and Reform Commission in China in a recent decision, rejected Qualcomm's royalty free grantback as restraining innovation and restricting competition in wireless communication technologies as a violation of the Anti-Monopoly Law 17(1)[14]. Qualcomm was fined 6.088 billion RMB in this decision, and was required to remove the royalty free grantback.

The 2004 EU *Technology Transfer Guidelines* proposed a different approach, suggesting that the seriousness of anticompetitive and, in particular, innovation concerns depended on the nature of the licensee's innovation. Grantbacks involving severable innovation – innovations that can be used independently or without infringing upon the licensed technology[15] – were viewed as more harmful than those applying to non-severable innovations, especially when the grantbacks were exclusive. This approach can also be seen in the Japanese Guidelines, where grantbacks of improved technology that must be used with the licensed technology (ie, non-severable innovation) would generally not be seen as impeding fair competition[16]. We allow for this distinction among technologies in our modelling and find that, indeed, technology type is an important contributor to both the use of grantbacks and their effects on innovation.

Publicly available legal advice on grantbacks seems unambiguous, as is the argument for why such clauses are necessary. In the words of one of many legal websites, "a properly drafted grantback license can encourage the licensing of technology by removing the fear that the licensor could find itself competing with a licensee who has developed an improvement to its technology." (McGurk, 2013) Our modelling allows us to test the validity of this "but for…" justification for grantbacks. The same legal advice states that, "an improperly drafted grantback clause risks being viewed as an anticompetitive provision that inhibits innovation." We also probe this claim[17].

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[14] See Section 2 NDRC Decision of Administrative Penalty 2015, no. 1, as cited in Ning, Gong and Li (2016).

[15] A licensee cannot exploit a *non-severable* innovation without a licensor's cooperation, whether because of infringement or because it must be used in tandem with the basic technology. We discuss severability and infringement further in section 5.

[16] See Japan Fair Trade Commission (2007) point 4.4.viii(c) and 4.4.ix(b) note 21.

[17] Leone and Reichstein (2012) cite academic papers going back to Davies (1977) making variants on this "but

Given this advice, one would expect that grantbacks would not be uncommon even if they carry some risk of being viewed as anti-competitive. Indeed, Cockburn (2007) finds that 43% of licensing contracts contain such clauses. Hence, while common and available, grantbacks are only accessed in some cases. This paper has multiple purposes, then: to investigate the conditions under which grantbacks would arise, their implications for innovation incentives, and the validity of both the publicly available legal advice for grantbacks and the appropriate policy response.

Others have had the same ambition, and indeed the economics literature has established some important results on grantbacks. Van Dijk (2000) shows that these clauses may decrease innovation incentives This decrease can improve welfare when the underlying incentives to invent (regardless of grantbacks) are socially excessive. Choi (2002) argues that there may be socially beneficial incentives to use grantbacks in situations of asymmetric information. These contributions leave scope for further work, however. Policy debate regularly calls attention to socially insufficient incentives to innovate, in contrast to the case treated by Van Dijk[18]. Furthermore, while asymmetric information certainly may be important in licensing negotiations, Moreira et al (2012) find that grantbacks tend to be more common among firms in the same product market and familiar with the relevant technologies, suggesting that the case of symmetric information remains empirically relevant.

Hence, in contrast to these papers, we consider a framework where there is an underlying socially insufficient incentive to innovate, and where information is symmetric across licensors and licensees. Consistent with our observations of practice, above, our model includes a licensor, a licensee and two markets separated by a transportation cost[19]. Also following observed practice, we allow licensing contracts to contain territorial restraints, i.e. clauses that reserve one of the markets to one of the two firms. Importantly, we assume that the licensing agreement enables the licensee to develop a "follow-on" improvement of the licensed technology. In this setting, we examine equilibrium behavior and innovation incentives under grantbacks and licensing in situations where the follow-on technology is severable and situations where it is not[20].

for" argument.

[18] Van Dijk's intuition for socially excessive incentives is outlined in Section 6. See Westmore (2014) for a policy discussion and Bloom et al (2013) or Denicolo (2014) for a general discussion of innovation incentives.

[19] Special cases of our model have zero or prohibitive transportation costs, although these are not a focus of our work.

[20] Kesavayuth (2017) investigates grantback design, comparing reciprocal to one-way grantbacks in an incomplete information setting where both firms can produce follow-ons and with two part tariffs. It is

We find that, for non-severable innovation, grantbacks are not necessary to ensure that follow-on innovation is undertaken where it is efficient in equilibrium. Indeed, the parties choose not to include grantbacks in the licensing contract in equilibrium precisely because both licensing parties internalize the costs of their negative effect on innovation incentives. Hence, our model suggests that, while we would expect licensing to be prevalent, we would not expect grantbacks to arise for non-severable innovations. As the parties choose not to include them, they have a neutral effect on the final licensing contract if they are permitted. Furthermore, we show that "but for" reasoning does not apply to this case.

On the other hand, we find that grantbacks of severable innovations can be necessary to induce technology diffusion. Severability allows the follow-on innovator to escape the royalty obligations of the original licensing agreement. Indeed, avoiding this royalty may be a spur to innovate. The resultant competitive threat means that the licensor may be better off not licensing in the first place. Furthermore, this outcome takes into account that the equilibrium licensing contract may reflect the cost of optimally blocking or deterring follow-on innovation. Finally, in contrast to the non-severable case, these results show that if we do observe licensing of severable innovations, we should expect the agreement to include a grantback for reasons captured by the "but for" argument.

In short, the severable/non-severable distinction is critical to licensing and innovation behaviour, with a more positive view of grantbacks emerging for severable follow-on innovations and following the reasoning contained in standard legal advice. This has policy implications.

The 2014 revision of the *EU Technology Transfer Guidelines* dropped the distinction between non-severable and severable innovations for grantbacks. Our analysis finds that the distinction is justified; however, our model implies the *opposite* of the 2004 *Guidelines*. This also applies to the Japanese Guidelines (which share the 2004 approach). Secondly, we find that grantbacks may or may not improve the total innovation incentives of the licensor and licensee, taken together, so that concern about innovation incentives may or may not be well placed. As the US draft Guidelines allow for a rule of reason approach, even though a severable/non-severable distinction is not drawn, this approach may be sufficient to ensure that socially beneficial grantbacks are promoted[21] as long as

complementary to ours, and its mechanism is linked more closely to Choi's (2002) underlying intuition.

[21] Choi (2002) points out that the Guidelines allow for an initial determination of whether the grantback significantly reduces the licensee's innovation incentive, and only if the answer is affirmative makes a determination of offsetting procompetitive effects. This would implement our conclusions if the procompetitive effects were to include the licensor incentives and the nature of the innovations in question.

arguments based on the nature of innovation and "but for…" reasoning are allowed.

Our model also contributes to the academic grantback literature in two ways. Firstly, we show that grantback clauses can arise in equilibrium even in the absence of asymmetric information and that their effects depend on their interactions with the type of territorial restraints that are typically found in licensing agreements. This makes our analysis complementary to Choi (2002), who focusses on asymmetric information and abstracts from territorial restraints. We investigate innovation incentives in the absence of underlying socially excessive incentives to innovate, making our analysis complementary to Van Dijk (2000) as well.

Our results also contribute to the literature on sequential innovation, following Green and Scotchmer (1995). We examine an environment where information diffuses through licensing rather than diffusing completely via the initial patent disclosure[22]. This means that the initial patent holder controls by means of licensing whether a sequence of innovations develops at all. This distinction in the channel of diffusion turns out to be critical. While Green and Scotchmer (1995) find that basic technologies should receive (infinitely) broad patents, we find in contrast that narrow patents could be preferable[23]. The reason is that while licensing is socially efficient under broad patents in the Green and Scotchmer (1995) framework, it is insufficient in ours because the basic technology holder can shut down future innovation completely by refusing to license in the first place. Narrowing the patent breadth tends to make future innovations severable and so "commits" the basic technology holder to share the future gains from the technology stream. A grantback allows sharing whilst returning gains from the follow-on innovation to the basic technology holder. This encourages the basic technology holder to initiate the sequence of innovations in the first place. Put differently, since information diffusion occurs via the licensing contract in our model, patent breadth is a less direct and so inferior tool to manage diffusion than licensing terms.

The remainder of the paper proceeds as follows. Section 2 outlines and motivates in detail the model

[22] We share this assumption with Choi (2002), Gallini and Wright (1990) and Rockett (1990), among others. Leone and Reichstein (2012) provide empirical support for licensing's facilitating licensee innovation where firms are familiar with the underlying technologies, as we assume here.

[23] We share Green and Scotchmer's (1995) assumption that only one firm is able to generate the basic technology, as this focuses attention most clearly on the role of our diffusion assumption. Other modifications, such as competition for the basic technology (Denicolo, 2000) or steady state analysis (O'Donoghue, Scotchmer, Thisse, 1998) also soften in a mechanism distinct from ours the argument for broad patent protection.

structure. Section 3 derives our results for the case of non-severable innovation, while section 4 considers severable innovation. Section 5 links our analysis to the analysis of patent breadth. Section 6 discusses extensions, including relaxing both our assumptions on bargaining and on information about the nature of follow-on innovation before that innovation occurs. Section 7 concludes.

2 Model structure

We present a simplified model that captures the salient features of licensing and grantbacks that we have outlined. Its structure is stark, so we investigate the role of our key assumptions in Section 6.

A licensor (firm *L*) patents a basic technology (*BT*). There are two markets: the patent-holder's "home" market and a "foreign" market. In each market the demand for a product that can be manufactured using the *BT* is perfectly inelastic : all consumers have a reservation price equal to 1 and there is a mass 1 of consumers.[24] The patent-holder can serve the home market at no cost. By contrast, serving the foreign market involves a per unit "transportation" cost requal to $c > 0$[25].

It follows immediately that if firm *L* were to commercialise its technology without relying on a licensee it would earn total profits equal to $Max\ [2-c,1]$. Alternatively, the patent-holder could serve the home market alone but could license another foreign firm – called firm *l* – to serve the foreign market[26]. If each firm enjoys exclusive use of the technology in its respective market, then they obtain joint surplus equal to 2. Licensing, therefore, leads to an increase in joint surplus equal to the efficiency gain $Min[c, 1]$.

We assume that the firms bargain over a per unit royalty, *r*, for the license[27]. It is then straightforward to check that the corresponding Nash Bargaining Solution splits this increase in surplus evenly between the two parties, i.e. $r = Min[c/2, 1/2]$.

The licensing contract specifies "territorial restrictions" such that the licensor is the only firm

[24] Assuming asymmetric markets with a mass of consumers *m>0* in the licensee's market does not affect the qualitative results.

[25] While we set up the model more broadly, we focus subsequently on the case where $c < 1$, so that "barriers to trade"are not prohibitive. If this is maintained then the "*max*" and "*min*" expressions above simplify.

[26] Choi (2002), footnote 13, provides empirical motivation for the assumption of a single licensee in the market.

[27] We rely on practical guidance for users such as WIPO (2015) to justify a use-based royalty. See Ambashi et al (2019) for more detail and Section 6 of this paper for an investigation of relaxing this assumption.

authorised to sell a non-severable product in its home-market while the licensee is given exclusivity in its own market. This assumption is motivated both by actual practice and current law[28].

We ignore further research efforts by the patent-holder, firm *L*, and focus our attention on the innovation activities of the licensee, firm *l*. We assume that use is necessary to improve a technology: firm *l* is completely unable to undertake improvements in the absence of a license. On the other hand, once firm *l* has become a licensee we assume that it can innovate immediately at a fixed cost, *F*. Such an investment succeeds with certainty and increases the consumer willingness to pay from 1 to $1+\theta$.

The licensee's follow-on innovation, dubbed *IT* for "improved technology", can be of two types: if it must be used in conjunction with the basic technology to generate value we call it "non-severable". If it can be used separately, we call it "severable"[29]. Therefore, in the severable case, firm *l* can sell a product of quality $1+\theta$ *whilst no longer owing any royalty payment to the owner of the BT patents*. Of course, all other features of the contract, in particular territorial restraints, remain in place as long as the firms access the *BT* patents, even though royalties are not owing due to lack of use. Royalties clearly do remain owing for non-severable improvements, as they require use of the *BT.*

The licensing game proceeds as follows. In Stage 1, the licensor decides whether or not to enter into negotiations with firm *l* about licensing the *BT*. In stage 2, the two parties negotiate the terms of the licensing contract, i.e. the usage-based royalty, r_1, that firm *l* commits to pay to the licensor as long as it uses *BT*. The two firms also negotiate the possible inclusion of a grantback clause. A grantback clause specifies that the *IT* must be made available to the licensor, although the territorial restrictions imply that each firm is free to use the technology in its own market only. Critically, we assume that the grantback clause does not specify any payment from the licensor in exchange for *IT*[30].

In stage 3, firm *l* innovates if it is profitable to do so, at fixed cost *F* and creating additional value θ. We assume that severability is already known to all in stages 1 and 2 so that we are either in a "severable innovation" case or in a "non-severable innovation case". We relax this assumption in Section 6. If the initial contract includes a grantback clause, then firm *L* also obtains access to *IT*.

[28]See Bleeke and Rahl (1979) and Ambashi et al (2016).

[29]Choi (2002) assumes innovation is non-infringing. We will return to a comparison of his results to ours in the section on severability as a result.

[30] This assumption allows us to concentrate on royalty free grantbacks, which are the more controversial type of clause and have been discussed extensively in the literature on practice and theory. See Ning, Gong and Li (2006), Green and Scotchmer (1995) and European Competition Law Annual (2005) as well as our working papers for further details.

Otherwise, the firms negotiate the access terms for *IT*. The outcome of this negotiation is a second royalty r_2 paid by firm *L* to firm *l*. In a final stage 4, both firms set prices and profits are realised.

3 Non-severable innovation

We first show that *BT* is licensed regardless of the inclusion of a grantback clause where innovation is non-severable, although the grantback clause weakens the incentive to generate *IT*. As non-severability implies that *BT* must be used in conjunction with *IT*, the agreed contract will ensure that the *BT* holder benefits from *IT.* Both technologies diffuse in equilibrium. Grantbacks as a tool for transferring surplus are not only superfluous, but also reduce the gains firm *l* can negotiate from *IT* and so reduce follow-on innovation incentives. As such, the parties agree not to include a grantback in the licensing contract.

The argument leading to this conclusion proceeds in two steps, which we sketch in the text with details included in Appendix 1. The first step shows that licensing always occurs regardless of the inclusion of a grantback, but follow-on innovation incentives may fall where grantbacks are present. Proposition 1 summarizes this result. Next, we show that the parties would not choose to include a grantback clause. This is summarised in Proposition 2.

3.1. Does Licensing Occur and Do Innovation Incentives Rise or Fall?

Our answer to this question is the following:

Proposition 1: *With a non-severable innovation, the basic technology always is licensed, whether or not the licensing agreement includes a grantback clause. Therefore, the "but for" defence does not hold. Incentives for follow-on innovation are weaker with a grantback clause so that there is a socially insufficient incentive to invent with grantbacks.*

The reasoning works backwards as usual. We treat no grantback and grantback cases separately.

<u>Case 1: No Grantback Clause</u>

Royalties and profits for for both firms, for a licensing contract that does not include a grantback or does include a grantback are listed in Table 1, with all calculations in Appendix 1.

Briefly, Firm *L* can only realise higher gains in its own market by purchasing access to *IT*, whilst firm *l*'s property rights on *IT* allow it to capture some of these gains using royalty r_2, which is determined by the following Nash Bargaining Solution :

$$\max_{r_2}[(1+\theta+r_1-r_2)-(1+r_1)][(1+\theta-r_1+r_2)-(1+\theta-r_1)] \quad (1)$$

$$\leftrightarrow \max_{r_2}(\theta-r_2)r_2$$

The resulting royalty rate listed in Table 1 as $r_2^{NN} = \frac{\theta}{2}$ [31], where "NN" stands for the case of "non-severable innovation and no grantback". Both firms thereby capture the entire social gain of $1+\theta$ instead of 1 in their respective home markets, plus any net royalty payments. Absent agreement at this stage, firm *l* must continue to pay the agreed royalty, r_1, if it wishes to practice its improvement in its own territory due to non-severability. Similarly, Firm *L* could continue to practice in its own territory and earn licensing revenues, per the original agreement, but would not benefit from access to the improvement[32]. As the royalty splits the gains from firm *L*'s exploitation of *IT*, firm *l* will invest if $F \leq \frac{3\theta}{2}$, even though innovation is socially beneficial if $F \leq 2\theta$. Hence, without grantback, there are socially insufficient incentives to create follow-on innovation in stage 3.

Assuming that the condition for *IT* to be innovated is satisfied, we move back to stage 2. Firm *L* anticipates that it will have to split its gains to *IT* in future licensing deals. Hence, it increases the licensing fee for *BT* to recoup this anticipated bargaining outcome. The bargaining at stage 2 splits the cost savings of entering into the licensing and innovation partnership: these are the gains from avoiding transportation costs by allowing the firms to sell under license in their own local markets and the future costs of generating *IT*. The resulting royalty is listed as $r_1^{NN} = 1 + \frac{\theta}{2} - \frac{c+F}{2}$ in Table 1, where the second term represents the future royalty payment and the final term reflects both transportation and future research costs[33]. The full set of royalty and innovation decisions from

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[31] We do not model the possibility that firm *L* would litigate because our assumption of information diffusion precludes it: as the *BT* license grants access in exchange for payment, there is no basis for litigation in later stages if payments continue, while if *BT* is not licensed *IT* cannot be created at all.

[32] This stage is an agreement on access terms for the improvement, so the disagreement payoff allows the original licensing agreement to remain in force. One might conceive of the *IT* license as the "reverse" portion of a cross license. The timing differs from standard simultaneous cross licensing, but sequential timing allows us to draw a parallel between our framework and earlier work on sequential innovation. See Section 5.

[33] See equations (A4)-(A5) in Appendix 1 and surrounding discussion for details on this set of results.

stages 2 to 4 generates gains to both firms, listed as $\pi_L^{NN} = 2 + \theta - \frac{c+F}{2}$ and $\pi_l^{NN} = \theta + \frac{c-F}{2}$ in Table 1, which exceed the respective no licensing payoffs of $\pi_L^R = 2 - c$ and $\pi_l^R = 0$, also listed in the table.

	r_1	r_2	π_L	π_l
NN ("non-severable, no grantback")	$1 + \frac{\theta}{2} - \frac{c+F}{2}$	$\frac{\theta}{2}$	$2 + \theta - \frac{c+F}{2}$	$\theta + \frac{c-F}{2}$
NG ("non-severable, grantback")	$1 - \frac{c+F}{2}$	N/A	$2 + \theta - \frac{c+F}{2}$	$\theta + \frac{c-F}{2}$
R ("No license")	N/A	N/A	$2 - c$	0

Table 1: Royalties and Profits for Non-Severable Innovation

Since the payoff to licensing exceeds that of not, licensing negotiations are initiated in stage 1 despite the fact that *IT* would result. Indeed, *IT* is a boon to the *BT* holder since the benefits from the anticipated improvements form part of the expected joint surplus. Since firm *l* cannot innovate without a license, firm *L*'s own pay-offs increase with the prospect and size of this innovation via the negotiated net royalty flows, shown in the table. The reasoning is analogous to that of Green and Scotchmer (1995) for infringing (non-severable) technology and without the possibility of grantback.

Returning to our focus, this result implies that the "but for" defence of grantbacks does not hold: the *BT* holder would license even without a grantback because she retains control over the entire stream of innovation under non-severability. This allows a favourable royalty to be negotiated despite the lack of prior agreement via a grantback. Still, without a grantback the agreed royalty for the improvement neither captures the full cost of innovation for firm *l* nor returns the entire social benefit of the stream of innovations to either firm. Socially insufficient innovation incentives result.

Case 2: Grantback Clause

We now analyse a licensing agreement that includes a (free) grantback. This means that firm *l* can no longer demand a royalty in return for *IT* in Stage 3, so that it will only invest in *IT* if the return in its home market exceeds the investment cost, i.e. if $F \leq \theta$. This range is smaller than in the absence of grantback, so that we can immediately conclude that a grantback clause reduces incentives for follow-on innovation in this case, as feared by Competition Authorities.

Since no royalty is due in stage 4, and focussing on the case where the home market is sufficient to generate firm *l*'s incentive to create *IT*, we move back to stage 2. Here, we see that firm *L* anticipates that it will gain access to *IT* royalty-free. This means that the royalty it charges for access to *BT* splits the gains from the trade cost savings and the direct cost of further innovation but is not adjusted for future royalty payments. Indeed, for our simple model, Appendix 1 shows that the stage 2 royalty exactly equals the *net* royalty earned by firm *L* without grantbacks. This can be seen by comparing the royalty in row two of Table 1, where "NG" represents the case of a non-severable innnovation with a grantback, to the net royalty when no grantbacks are available, $r_1^{NN} - r_2^{NN}$.

The net royalty is the same regardless of the grantback, so the profits of firms *L* and *l* are exactly the same in both with and without the clause[34]. The equilibrium outcomes are summarised in Table 2.

Innovation Cost	No GB	GB	Effect of GB	But-For Defence
$\boldsymbol{F > 3\theta/2}$	Licensing, no innovation	Licensing, no innovation	None	No
$\boldsymbol{\theta < F \leq 3\theta/2}$	Licensing, innovation	Licensing, no innovation	Discourages Innovation	No
$\boldsymbol{F < \theta}$	Licensing and innovation	Licensing and innovation	None	No

Table 2: Equilibrium Outcomes with Non-Severable Innovation

We can see that grantbacks have negative innovation effects in this case. Because *IT* is non-severable, the licensee can only exploit it in its own territory under license, regardless of the grantback clause. Absent the grantback clause, however, the licensee can extract its own royalty payment from firm *L*. This increases firm *l*'s incentives to innovate, even though they remain socially insufficient. Since this royalty payment is fully anticipated by both parties, however, it adds to firm *l*'s share of total surplus in the stage 2 negotiations on the *BT* royalty. Overall, then, the inclusion of the grantback does not affect how rents are shared. This concludes the argument establishing Proposition 1.

3.2. Would the Parties Choose to Include a Grantback Clause?

Since the grantback only affects pay-offs for intermediate values of *F*, as shown in Table 2, this is the only case we consider here. Over this intermediate range the argument for Proposition 1 implies that both firms are better off without a grantback clause precisely because eliminating the grantback

[34] If $F > \theta$, there is no follow-on innovation and the pay-offs are obtained by setting $\theta = F = 0$.

extends the region for which follow-on innovation occurs to $F \leq \frac{3\theta}{2}$ from $F \leq \theta$. From Table 1, we see that all parties do better with innovation than without, as the benefits are shared through the licensing royalties. This argument establishes the following proposition:

Proposition 2: *If the follow-on innovation is non-severable and the inclusion of a grantback clause is determined as part of the negotiation process, then the parties agree not to include a grantback clause.*

4 Severable innovation

In the case of severable innovation, and in the absence of a grantback clause, firm *L* cannot extract any royalty payment from firm *l* in return for transferring *BT* in stage 2 even if *IT* occurs in stage 3. This follows from our stark assumptions that follow-on innovation occurs immediately, potentially making *BT* "obsolete"[35], and that royalty payments are linked to use. In our model, then, firm *l* learns from licensing *BT* but does not actually employ it in production because *IT* "leapfrogs" *BT*. This structure, while specific, allows us to focus on the economics behind the "but for" defence[36].

Proposition 3 summarises our result, derived as a series of figures in the text and a series of lemmas in Appendix 2 (no grantback case) and 3 (grantback case)[37]. Figures 2 and 4 carry the main results on licensing conditions in the no grantback and grantback cases, which are then compared in Figure 5.

Proposition 3*: With severable innovation and a grantback regime where innovation allows the licensee to escape royalty payments, the owner of the basic technology offers a license only if the innovation is large enough, or the cost of innovation is large enough. Licensing leads to innovation only if the size/cost "efficiency" ratio of the innovation is sufficiently large. Conditional on the parties reaching a licensing agreement, the licensee's incentives to innovate are socially optimal. Otherwise, innovation incentives are socially sub-optimal.*

We break separate the cases of no grantbacks and grantbacks, as before.

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[35] In other words, "obsolescence" refers to the outcome that, in equilibrium, firm *l* will limit price so that *BT* is driven from the market in head-to-head competition between *IT* and *BT*. See Appendix 2 for details.

[36] Moving moderately away from the assumptions that *IT* is innovated immediately or that royalties are conditioned upon use does not modify the qualitative results. Details are available from the authors.

[37] See also our extended text treatment in Ambashi et al (2016).

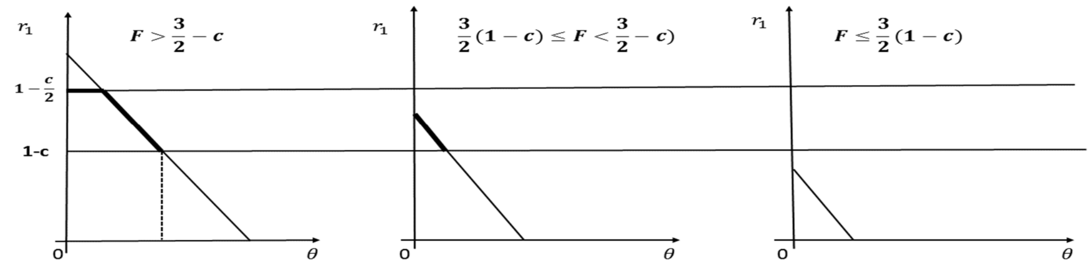
Case 1: No Grantback Clause:

In the severable case, firm *l* can "escape" the royalty payment for *BT* by means of *ex post* innovation. This is because severability implies that *IT* can supplant *BT* without any continuing royalty payments to firm *L*. At the same time, firm *l* will only invest in *IT* at cost *F* if these royalties are sufficiently onerous: firm *l* can alternatively produce using *BT.* The possibility of "escape" imposes, then, a natural limit on the royalties that firm *L* is able to extract.

This natural limit on the royalty, r_1 is illustrated in Figure 1, below, as a negatively sloped line. Lemma 1, derived and stated in Appendix 2, contains the full mathematical expressions for the three ranges of the parameters generating panels *a*, *b*, and *c* of Figure 1. We focus in the text on the elements of that derivation that are crucial to the intuition for the results of this case.

First, consider panel *a*. A comparison of firm *l*'s profit from innovating or not innovating generates a negatively sloped constraint describing a "limit" *BT* royalty that is low enough that firm *l* would not innovate, described by the equation $r_1 = F - \frac{1-c}{2} - 2\theta$. The upper horizontal line is the optimal unconstrained royalty when no follow-on innovation occurs, $r_1^* = 1 - \frac{c}{2}$. The chosen royalty will never exceed this level. The bottom horizontal line represents the minimum royalty for which firm *L* would prefer to license *BT* instead of not licensing, or $1 + r_1 \geq 2 - c$.

Combining these together, the heavy line shows the eqilibrium choice of royalty. For low values of θ the temptation to innovate *IT* is low so that the unconstrained royalty r_1^* does not trigger *IT*. For higher values of θ such that r_1^* would trigger *IT*, r_1 becomes constrained. We could think of the royalty becoming more constrained as the follow-on innovation process becomes more "efficient", defined as a higher ratio of benefit, θ, to cost, *F.* Indeed, as the level of *F* falls across panels *b* and *c* the constraint shifts in, so that the unconstrained royalty will never be chosen (panel *b*) or firm *L* no longer wishes to license (panel *c*).



(a) "inefficient innovation": optimal or constrained royalty

(b) "moderate efficiency": constrained royalty

(c) "efficient innovation": no licensing

Figure 1: Royalty Setting under No Grantback

Lemma 1, contained in Appendix 2, restates the results illustrated in Figure 1 as formal ranges of the "efficiency" ratio of θ to *F* for which licensing will occur and the corresponding royalty rate that will be chosen. While it might be surprising that firm *L* licenses at all, given that *IT* can render it obsolete, recall that firm *L* controls the diffusion process that makes *IT* possible in the first place. This allows the *BT* license to act as a tool to extract profit from *IT*. Equally, while the *BT* license facilitates obsolescence, it also comes at a cost to firm *l*.

Figure 2 depicts Lemma 1 as the ranges of efficiency for which *BT* is licensed and the unconstrained royalty r_1^*, or the constrained royalty r_1^{lim}, respectively, are chosen. As the figure is drawn in (θ, F) space, innovation efficiency increases to the south-east. As *IT* becomes more efficient, it becomes harder for firm *L* to make the licensing contract tempting enough to keep rather than escape by further innovation. If *IT* is too tempting, firm *L* can find no license that remains attractive for it to offer and so does not initiate licensing negotiations. As we have assumed that royalties are conditioned upon use and that no time passes between receiving *BT* and innovating *IT,* our modelling allows us to underline the "escape royalty" effect and the resulting royalty cap on the basic technology innovator.

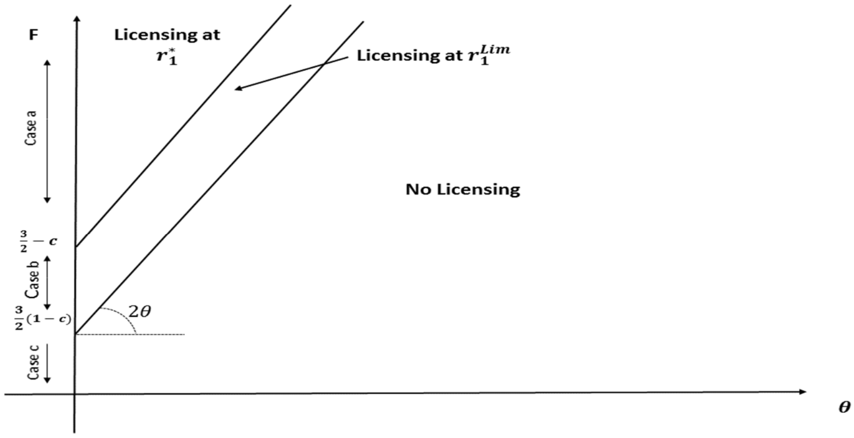


Figure 2: Licensing Conditions under No Grantback

Figure 2 shows that follow-on severable innovation never occurs for three reasons. *IT* may be inefficient enough that innovation is "blocked" by its own cost. Equally it may be blocked because no *BT* license issues. *IT* may also be "deterred" by the royalty "cap" on *BT*. All three generate higher profits for firm *L* than accommodating *IT*: firm *L* cannot profit from exploiting *BT* itself if it is leapfrogged by a severable technology nor can it "tax" firm *l* if *IT* is severable.

Lemma 2: *With severable innovation and no grantback, the basic technology is only licensed if the follow-on innovation is sufficiently inefficient. The licensee of the basic technology never chooses to innovate in equilibrium.*

The constrained royalty case recalls the intuition for Gallini (1984), whereby a licensor allows access to her technology in order to discourage a potential entrant from researching a potentially leapfrogging technology. Gallini asks whether the *BT* contract can issue on sufficiently favourable terms to deter the licensee from incurring the expense of another technology "draw", where such deterrence can be socially desirable because it reduces duplicative R&D expenses, i.e. because the entrant's incentives to innovate might be socally excessive. In contrast, we focus on the case where private incentives to innovate are too low. Here, the potential benefit of favourable licensing terms is that they discourage follow-on innovation, which can in turn encourage *BT* licensing in the first place.

Choi (2002) finds that "core" technology that promotes severable "leapfrogging" innovation will be licensed where markets are separate and take-it-or-leave-it fixed fees allow the licensor to capture any follow-on gains upfront alongside promoting efficient production. Quantity-based royalties arise only under incomplete contracting to incentivise licensors to reveal and license such "facilitating" technologies. Grantbacks can improve contract efficiency by lowering royalty payments since they partially solve the *BT* licensor's incentive problem. We study (partially) linked markets and Nash Bargaining so that fixed fees do not fully resolve the leapfrogging problem under complete contracting. The *BT* licensor may not license and, if it does, the royalty may be set to disourage leapfrogging. We show in the next section that modified, but not necessarily lower, royalty levels and grantbacks may be used to resolve this alternative set of inefficiencies.

Case 2: Grantback Clause

As *IT* is now severable, firm *L* cannot legally collect royalties on *BT* if it is no longer used by the licensee[38]. This means that the grantback cannot require such payments. Despite this, the territorial restrictions included in the *BT* license apply to all products that rely on *BT*. The grantback can also carry its own territorial restrictions and in particular, the parties may agree that the grantback prevents the firms from exploiting *IT* in each other's home markets. We assume that the grantback includes such restraints. As the reasoning is analogous to earlier sections, a time constrained reader may wish to skip to Figure 4 and the discussion following it.

One might think that, since any agreed royalty would not be collected anyway when innovation occurs, the only relevant decision for the licensor is whether or not to offer a license to firm *l*. The decision is more complex, however. Firm *l* compares setting a price equal to $1+\theta$ at home (and protected by the territorial restraints) to the pay-off from setting a price equal to 1 whilst continuing to pay to access *BT*. A higher royalty for *BT* therefore incentivises firm *l* to innovate in order to escape the royalty payment, just as before. Hence, *IT* continues to constrain the initial licensing decision and so affects both the *conditions* and the *occurrence* of licensing. In contrast to the previous case, the grantback protects firm *L* against leapfrogging not only by allowing access to *IT*, but also by allowing it to benefit from continuing territorial restraints. This affects the optimal royalty level r_1 and so affects the subsequent innovation decisions of firm *l*. As the grantback provides better "insurance" against firm *L*'s potential losses from leapfrogging, *BT* will be licensed for a larger parameter range. This generates welfare gains to grantbacks that derive from "but for" reasoning.

More precisely, firm *L* has three options: not license yielding profits of $2-c$, license with a royalty low enough to make further innovation by firm *l* undesirable whilst leaving firm *L* with profits equal to $1+r_1$, and license with a royalty that is high enough for innovation to occur, yielding a profit of $1+\theta$: firm *L* neither receives licensing income under our stark assumption that *IT* occurs immediately, nor

[38] The legal issue would be whether payment is extracted for a technology that is not used, not whether the payment for use is spread over a longer period than actual use.

pays for access as the contract includes a free grantback. Figure 3, drawn analogously to Figure 1 in (θ, r_1) space, illustrates the horizontal, vertical and diagonal $(45°)$ conditions that determine firm *L*'s preferred outcome among these three options: $(1+r_1) \gtrless (2-c)$; $(1+\theta) \gtrless (2-c)$; $(1+r_1) \gtrless (1+\theta)$. Firm *l'*s optimal reaction may constrain these options, however. The optimal innovation choice of firm *l* is determined by comparing the payoff to innovating or not given that licensing has occurred:

$$1 + \theta - F \geq 1 - r_1 \leftrightarrow r_1 \geq F - \theta \tag{2}$$

We superimpose this inequality on the figure as a negatively sloped "improvement constraint". We state in the figure firm *L'*s preferred feasible outcomes, taking into account the decisions of both firms, in each region. For brevity, we have illustrated only one specific parameter range, $1 - c < F \leq 2(1-c)$, with other ranges and outcomes illustrated in Appendix 3. Like Figure 2, as efficiency increases the relative position of the negatively sloped diagonal "improvement constraint" shifts in.

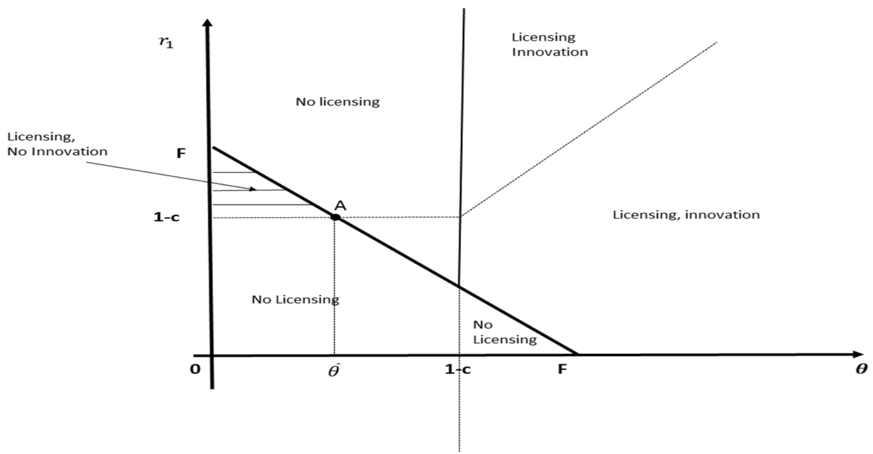


Figure 3. Firm *L*'s Preferred Feasible Outcomes, Moderate Efficiency, Grantback

Assuming that firm *L* chooses to license *BT*, we must now determine the outcome of the stage 2 negotiations about royalty r_1. The reasoning is analogous to our earlier analysis with the exception that in this case *IT* generates no royalty under the grantback scheme and also effectively renders *BT* obsolete so that *BT* will no longer generate royalties either. If innovation is very efficient, either *BT* is not licensed at all or, if it is, *IT* occurs as detailed in Appendix 3. At lower efficiency levels, regions emerge where no licensing, licensing with no follow-on innovation, or licensing with innovation occur in equilibrium. The royalty must be capped at $r_1^{Glim} = F - \theta$ to deter *IT* when efficiency is above a threshold level, as detailed in Lemma 3 of Appendix 3. $\bar{\theta}$ depicts the efficiency limit for deterrence with licensing.

Figure 4 completes the argument for Proposition 3. It illustrates the equilibrium outcomes once all the ranges of efficiency are superimposed and both firms' behaviour is taken into account. The two horizontal constraints delineate regions where *IT* is highly inefficient, moderately efficient, and very efficient. The vertical constraint delineates regions where *L* prefers not to license (left) to the alternative of licensing that triggers *IT* (right). The diagonal constraints divide regions where firm *L* prefers licensing at a capped rate (left) to not licensing at all (right of flatter constraint) or licensing with innovation (right of steeper constraint). LNI means "licensing, no follow-on innovation" and LI means "licensing with follow-on innovation" in the figure.

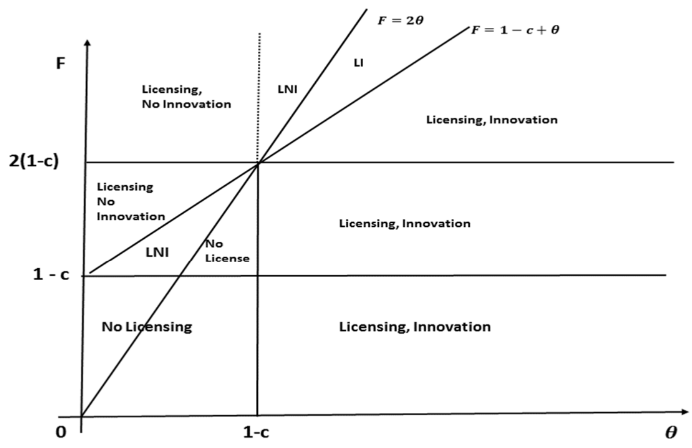


Figure 4: Equilibrium Outcomes with Severable Innovation and Grantback

This analysis leads to several observations. Firstly, even with the grantback clause, *BT* is not always licensed when it would be socially efficient to do so. Although firm *L* would be happy to license at an unconstrained royalty and without the threat of obsolescence, these two conditions cannot be met simultaneously: any royalty that would induce firm *L* to license would also trigger *ex post* innovation and make firm *L*'s technology effectively obsolete. Conditional on licensing, however, incentives for *IT* are optimal since innovation occurs everywhere below $F = 2\theta$ line and to the right of $\theta = 1 - c$. This optimality results from the *ex ante* nature of the grantback: the fixed cost of innovation is not yet sunk at the time the grantback is negotiated, so that the parties can agree to split the surplus without suffering from the hold up properties of an *ex post* license. In this sense, the grantback does not hamper innovation incentives. Finally, comparing Figure 4 to Figure 2 (and Lemma 2), we note that licensing may generate follow-on innovation in equilibrium under grantbacks, in contrast to the case of no grantbacks. We turn to the intuition for this in the following section, as it is key to our argument.

4.2.3 In Defence of the "But For" Defence

We can now compare the outcomes with and without grantback, resulting in the following proposition:

Proposition 4: *With a severable innovation, a grantback clause increases the range of parameters for which licensing and innovation occur, with an intuition compatible with a "but for" defence.*

To illustrate the reasoning behind Proposition 4, Figure 5 superimposes Figure 2 on Figure 4. The dotted diagonal lines are those of Figure 2 and represent the regions for which licensing (but no further innovation) occurs without a grantback. The solid lines represent the regions for the licensing configurations with grantbacks from Figure 4. The text in the figure represents the licensing outcomes for those regions under grantbacks. Without grantback, *BT* licensing only occurs above the lower of the two dotted lines and never results in follow-on improvements; with grantbacks, *BT* licensing occurs for all except the "no licensing" region in the lower left hand corner.

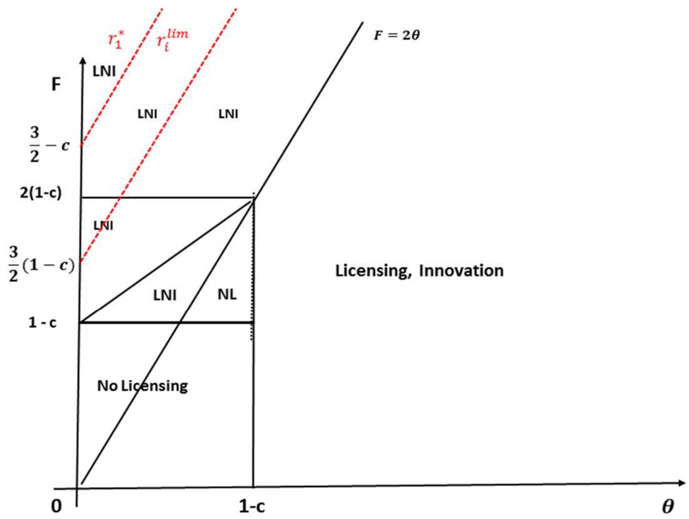


Figure 5: Comparing Outcomes with and without Grantback Clause[39]

Combined with Proposition 3, it is immediate that the grantback clause not only promotes licensing, but also promotes licensing that gives rise to efficient follow-on innovation. Put differently, efficient follow-on innovation accompanies licensing now instead of deterrence.

Intuitively, with severable innovation firm *L* knows that it cannot secure any royalty payment for *BT* if

[39] The graph is drawn with the intercept of the dotted line below 2(1-c). This restriction has no qualitative effect on the analysis.

firm *l* innovates. Furthermore, in the absence of grantback firm *L* knows that it will have to pay a royalty in order to avoid being rendered obsolete by *IT.* This scenario is unattractive enough that firm *L* only licenses if innovation is sufficiently inefficient that a royalty can be found that remains attractive to firm *L* whilst not tempting firm *l* into innovating. Otherwise, firm *L* simply declines to license at all: licensing under severability creates a replacement effect that is large enough that the status quo is preferable. With grantback, firm *L* is guaranteed free accces to *IT*. This has two effects. Firstly, because the free grantback does not allow firm *l* to obtain revenues from the *BT* owner, firm *l*'s incentives to innovate are reduced. Firm *L*, is therefore able to include a higher royalty in the initial contract without triggering *IT*, which improves firm *L*'s incentives to license. Secondly, even if licensing leads to *IT*, firm *L* can now exploit this innovation at home for free. If *IT* is sufficiently beneficial, this is attractive.

This intuition is compatible with the "but for" defence. Firm *L* needs the licensee's expertise, as it cannot generate *IT* on its own and cannot serve the foreign market as efficiently as the local firm in any case. At the same time, without a grantback, *BT* licensing creates the threat of obsolescence or, if firm *L* wishes to avoid obsolescence, occasions a steep royalty payable to firm *l* for any improvement. With the grantback as a guarantee not to be caught in such an undesirable bargaining position, the *BT* owner is more willing to license, even at a depressed royalty rate. Indeed, firm *L* deters innovation via "market sharing" where it is socially efficient to do so, since the two firms are able to bargain *ex ante* on the agreement. As the "but for" defence did not find support in the case of non-severable innovations, the type of follow-on is key to this defence. We return to this point below.

4.3 Would the Parties Choose to Include a Grantback Clause?

Finally, we need to determine whether the parties would choose to include a grantback clause in the initial licensing agreement when innovation is severable. When the follow-on innovation is efficient grantbacks are favoured by both firms as they reduce the reluctance of the initial innovator to license. On the other hand, the incentives of the two firms are opposed for intermediate ranges of efficiency: the licensee's bargaining position improves with no grantback, affecting the range and level of the royalty cap. The result is stated below.

Proposition 5: *If the follow-on innovation is severable, the parties would agree to include a grantback clause as long as follow-on innovation is sufficiently efficient. This grantback clause improves social welfare since it allows for licensing and innovation for parameter ranges where licensing would otherwise not occur but where it is socially desirable. In such cases, the "but for" defence applies with full force. For very inefficient follow-on innovation, both parties are indifferent with respect to the grantback clause. For an intermediate range of follow-on efficiency, the initial patent owner favours including a grantback while the licensee opposes it.*

We refer again to Figure 5. Above the upper diagonal dotted line, licensing at the optimal royalty occurs regardless of grantbacks, making the two firms indifferent about including the grantback clause. Below the lower of the diagonal dotted lines licensing occurs with grantback but does not occur without grantback so that both parties are better off with a grantback clause: firm *l* because it makes positive profits rather than being "frozen out" of *BT*, and firm *L* because it is able to tap into *IT* or at least to share the market so as to reduce transportation costs, both at a profit.

The argument for the grantback is less clear over the range for which licensing occurs both with and without grantback but where no grantback is associated with a royalty cap. This occurs between the dotted lines in Figure 5. Here, licensing will not generate *IT* regardless of the grantback clause: firm *L* "shares the market" in order to avoid obsolescence. On the other hand, firm *L*'s alternatives differ depending on the grantback, and this can affect the level of royalty at which it "shares" the market. Hence firm *L* would suppport having a grantback clause, whereas firm *l* would resist it. Note that, compared to Choi's (2002) framework, the grantback need not reduce the royalty rate. This is because the royalty serves very different functions in the two papers: in Choi's it is required to achieve incentive compatibility for the quality of the transferred *BT*. In ours, it is a tool to incentivise the licensee's innovative effort.

At intermediate and higher ranges of transport cost, cases also occur where the royalty is constrained both with and without a grantback. This can also lead to opposing interests. Figure 6 shows the upper part of Figure 5[40] for sample parameter range $\frac{1}{2} < c < \frac{2}{3}$. We have added the line $F = \theta + 1 - \frac{c}{2}$, above which licensing with grantback occurs at the "interior" optimal royalty r_1^* and below which we have a constrained royalty. For the area between the dotted lines but also below the newly added line, licensing with no follow-on occurs at $F - \theta$ with a grantback and at $F - \frac{1-c}{2} - 2\theta < F - \theta$ without, leading the licensee to oppose a grantback but the licensor to support it[41].

[40] Shown for a specific ranking of the vertical intercepts and diagonal lines. This selection does not affect the qualitative conclusions.

[41] Low values of θ – "duds on the market" – are possible regardless of innovation type, as are high values of θ – "superstar performers". Still, empirically some regions may occur less frequently for certain innovation types, making certain regions less relevant in some cases. Efficiency remains the determinant measure, however, rather than innovation value, as can be seen by the generally diagonal division of the space into behaviours.

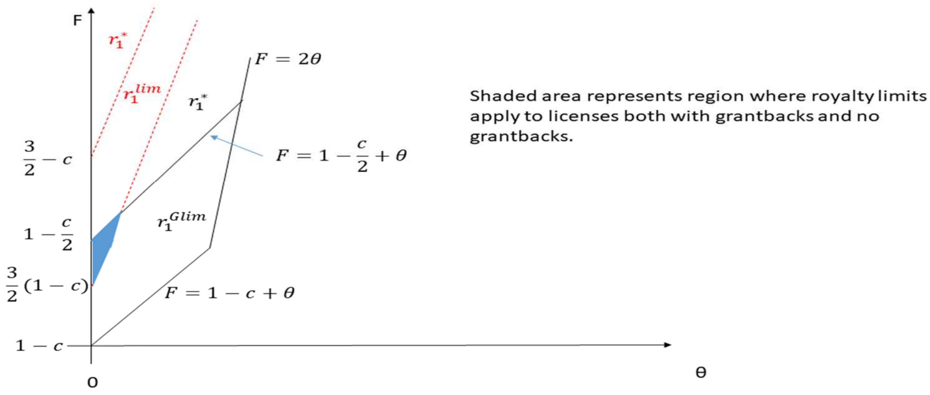


Figure 6: Upper Portion of Figure 5 with Royalty Limits Added

5. Patent Scope and Grantbacks

Because *IT* follows the development of *BT* and is enabled by it, our analysis addresses the question of how sequential innovators can contract in order to ensure an efficient division of rents. There is by now an extensive literature on sequential innovation.[42] The contribution that is closest to ours is Green and Scotchmer (1995). These authors consider a situation where patenting a first innovation enables another firm to invest – and obtain – an improvement on the initial technology. Green and Scotchmer consider both *ex ante* licensing (i.e. before the second firm invests) and *ex post* licensing and discuss the socially desirable strength of the “novelty reqirement”. This requirement refers to the required size of the *improvement* contributed by the second innovation to avoid infringing the patent of the first innovator, or the “vertical scope” of the patent. They conclude that, provided that the licensor and licensee can “collude” in the pricing subgame that follows the second innovation, the “vertical scope” should be infinite. Intuitively, collusion ensures that the two innovators jointly obtain as much surplus as possible, whilst infinite scope delegates control of the process generating that surplus to the initial innovator. *Ex ante* licensing guarantees in addition that the first innovator takes into account the investment necessary to obtain the second innovation.

There is a clear parallel between infringement and non-severability, allowing us to compare our results to theirs. Like Green and Scotchmer we assume that there is no racing at any stage of the innovation process: the licensor obtained the first innovation and the licensee is the only one who can obtain the

[42] See, for example, Scotchmer and Green (1990), Scotchmer (1991, 1996), ODonoghue et al(1998) and Denicolo (2000) among others. Rockett (2010) provides a review.

follow-on. In this sense, we examine “scarce ideas” as they do. Furthermore, the limit case where trade barriers between our two markets tend to zero is equivalent to the single-market case analysed by Green and Scotchmer; however, the territorial restraints that firms use in practice allow the firms a tool to implement the analog of Green and Scotchmer’s “collusion” by allocating markets.

In our framework, parties chose not to use a grantback clause, and the licensor’s incentives to innovate were socially insufficient, where improvements “infringed”. Parties would use a grantback for “non-infringing” and efficient innovation, the licensee’s incentives to innovate would be socially optimal, and the licensor’s incentives to license would improve. In our setting, then, extending the “vertical” scope of protection to ensure that the follow-on innovation infringes the *BT* patent is *not* desirable.

Aside from modelling the grantback clause as part of the license, which makes explicit our form of *ex ante* licensing, two main differences exist between Green and Scotchmer’s framework and ours. First, the mechanism of knowledge transmission differs. Green and Scotchmer assume that the patent reveals sufficient information about the first innovation to enable the second firm to obtain the follow-on improvement. By contrast, we assume that the follow-on innnovation can only be achieved if the second firm obtains a license that allows it to learn from practicing the basic technology. Because of this difference in information transmission, the initial innovator finds itself in a stronger position in our framework: it can always prevent follow-on innovation by refusing to license. As such, there is less need to “strengthen the hand” of the first mover by granting it a patent with a large vertical scope[43].

Second, and important where there are barriers to trade between our two markets, the follower could choose to license the improvement back to the initial innovator if the grantback is not present. This possibility means that the initial innovator can extract a good deal when reaching a licensing agreement with grantback. This, in turn, ensures that the second mover gets sufficient incentives to innovate precisely to escape this royalty. This balance of bargaining power can generate efficient outcomes in the absence of additional strength imparted to the initial innovator via wide patent scope.

6. Extensions

Our results were obtained in a model with specific assumptions; however many can be dropped or modified without affecting the nature of our results. For example, a time lag to the date of improvement or probabilistic innovation would not affect our qualitative results.

More substantively, we have assumed that trade barriers are not high enough to fully isolate the

[43] Reality likely falls between the extremes of revelation purely via the patent disclosure and revelation via the license. Our modelling is stylised to emphasise the underlying mechanism.

markets, even in the absence of follow-on innovation ($c < 1$). Relaxing this assumption does not affect the analysis of non-severable innovation for two reasons. Firstly, the fact that firm *l* cannot use *IT* without continuing to rely on *BT* ensures that "inter-market" competition is not an issue regardless of trade barriers. Secondly, increasing trade barriers makes licensing more attractive to firm *L* since this decreases firm *L*'s ability to serve customers outside of its home market. Licensing always occurred in the non-severable case for smaller trade barriers, so it will still occur when barriers become substantial.

Turning to severable innovations, high trade barriers eliminate the regions in Figure 3 where θ and *F* are both smaller than $1 - c$, shrinking the region where the firm *L* chooses not to license *BT*: in order to extend the reach of *BT*, firm *L* must now license since it cannot enter abroad on its own. Where no grantback is present, the region where firm *L* would wish to license without triggering follow-on innovation shrinks. This is because triggering *IT* whilst remaining the local supplier of *IT* under license more easily dominates for firm *L* since the competitive threat from abroad is lower. Furthermore, there is little reason to cap the royalty in this case, since there is little reason to incentivise firm *l* to refrain from innovating. Hence, grantbacks become relatively less desirable since the royalty is limited over a smaller range, making the argument for grantbacks less compelling in this case: the "but for" argument has at its basis the threat of entry in the *BT* owner's market by the licensee, so that when this threat is reduced the argument for grantbacks also becomes weaker.

Another feature of our analysis is that we assumed that all parties knew *ex ante* whether *IT* was severable. Severability may indeed be predictable in advance where research is "directed" and the parties are both experienced in the market. Information may be less complete in general, however; and if property rights are probabilistic in their scope, infringement may not be determinant. While determinant severability has allowed us to highlight the role it plays in optimal contract design, it would be well to know what changes when this extreme case does not hold[44].

We implement this in a model, modified for tractability, and presented in Appendix 4. That appendix derives three propositions that summarise our results. Intuitively, the results of this case look rather like the non-severable case where severability is unlikely and like the severable case otherwise. Under no grantbacks, the more likely is severability, the more costly it is for the licensor to deter *IT* by reducing r_1, since the licensee's incentive to innovate to escape the royalty is correspondingly larger. Hence, the licensor must set an even lower royalty as the probability of severability rises, whilst the

[44] We present the details and a more extensive text presentation of this extension in our working paper, Ambashi et al (2019).

likelihood that it is ever collected simultaneously falls. This results in no licensing persisting in equilibrium and becoming more likely as the probability of severability increases. The region where no licensing is preferred shrinks, of course, as the efficiency of *IT* increases since the "pie" to be shared increases where *IT* is more efficient. Indeed, equilibrium configurations involving licensing with innovation occur even for high likelihood of severability.

Turning to welfare, this, as well as the parties' joint surplus, is maximized with licensing. Innovation remains socially optimal if the cost of innovation does not exceed the additional surplus generated or $F \leq 2\theta$. This means that equilibrium configurations with no licensing are inefficient and associated with insufficient innovation.

New to the analysis, however, is that socially excessive innovation can also arise where it did not in the extreme cases in the main text. To understand this result, note that as long as the probability of severability is positive the licensee has the possibility to escape r_1 by innovating. In turn, the licensor can use a large royalty to induce follow-on innovation if it so desires. Indeed, by charging a high enough royalty, the licensor can induce the licensee to innovate even where it is inefficient to do so. Furthermore, the higher the chance of severability, the stronger this effect. At the same time, a higher chance of severability also means that there is less threat that r_1 will remain payable. Indeed, in such a case, *IT* could command a high royalty of its own. The inter-play of these forces is non-linear and so excessive innovation arises for intermediate probabilities of severability. Where the innovative step is large enough, the incentives to innovate can never be excessive, although they may be inefficient. For smaller innovative steps, the incentives to innovate may be excessive where the probability of severability is high enough but may be insufficient otherwise. Note that this mechanism to generate excessive innovation is distinct from the excess innovation of Van Dijk (2000), where duplication of effort between two firms racing for the same innovation is the root cause.

Overall, then, the upshot of this extension is that the grantback clause can be socially desirable if the probability of severability is large enough precisely because it leads to greater incentives to innovate, although this can even result in excessive innovation. As the follow on is less likely to be severable, this advantage of grantbacks decreases and eventually reverses because, as we saw in the basic model, the grantback reduces the licensee's ability to extract payment for its own innovation whilst at the same time the probability of non-severability limits the ability of the licensee to escape any royalties due on *BT.* Linking this to the results in Section 5, we see that patent scope and grantbacks generate social optimality in innovation incentives (or not) jointly in this setting. In environments where patents are narrow, so that the probability of severability is high, grantbacks tend to be more desirable; where patents are broad and the probability of severability is low, the argument is less compelling.

Finally, the type of follow-on innovation could itself depend on the licensee's R&D efforts, so that the probability of severability may be endogenous. If the licensee can select the innovation type after settling the contract terms, then for the same innovation cost, *F*, it would always choose severability. If severability is more costly this is less clear: the extension we have just outlined suggests that a licensee prefers a higher ratio of $\theta + s$ to *F* via either increased severability or increased inherent benefit, where *s* is the probability of severability[45]. Firm *L* would need to structure the initial licensing negotiation as a principal incentivising an agent to improve its innovation "technique", which is not a question we address. Further, we have assumed no asymmetric information on the type (or size) of follow-on innovation and this further consideration could introduce both additional constraints and possibilities to the licensing contract.

7. Conclusion

Grantback clauses specify that a licensee must "return" improvements on the licensed technology to the patent-holder. They are a common feature of licensing agreements. The main policy concern raised by such clauses is that they might reduce the innovation incentives of the licensee[46]. Following the former approach of European competition Law, we distinguish between follow-on innovations that are severable from the original patent and those that are not. For non-severable innovations we find that grantback clauses would indeed reduce the licensee's incentives to innovate. However, this effect should not be a concern since we also show that in such cases the parties would agree not to include a grantback in their licensing agreement. When the follow-on innovation is severable, we find that the parties choose to include a grantback in the licensing contract and that the inclusion of the grantback clause actually helps to ensure that the licensee has socially appropriate incentives to innovate. Within our framework, then, the distinction in some competition law treatment of grantbacks between severable and non-severable innovation is appropriate. On the other hand, our results suggest the

[45] O'Donoghue et al (1998) extend their model of the scope of patent rights to endogenous "step size" in a quality ladder model, finding that "overly large" steps can result. In that paper, the policy maker controls the equivalent of severability, whereas here severability and quality could potentially both be under the control of the licensee – at a cost.

[46] We do not address here the incentives to innovate the basic technology, which our model takes as already invented. Our model implies, trivially, that the existence of the *option* of a grantback increases the incentive to innovate for the basic technology owner, since the contract option cannot decrease and may increase the earnings of both parties from the stream of innovations. This is particularly true for severable innovations in our model, as grantbacks are not selected in equilibrium in the non-severable case.

opposite treatment from that followed in some jurisdictions for these two types of innovation, with grantbacks less of a concern for severable than for non-severable innovations.

We derive these results in the context of what we observe to be the most common setting for grantbacks: innovation incentives are socially insufficient, licensing occurs among firms familiar with the underlying technologies, and other standard contract provisions such as territorial restraints are allowed. Our setting assumes that access to a basic technology via a license substantially enhances a licensee's ability to improve on an innovation, an assumption recently supported empirically by Leone and Reichstein (2012).

Our framework allows us to examine the settings to which a common legal defence of grantbacks, which we dub the "but for" defence, applies. While our observation that publicly available advice relies on "but for" reasoning is our main empirical motivation, Cockburn (2007) and older work by Caves, Crookell, and Killing (1983) suggest that grantbacks are common although not ubiquitous. As our framework implies that grantbacks should be more prevalent only where innovations are likely to be severable, whereas papers such as these aggregate over innovation types and informational settings, this earlier work cannot provide direct evidence for our results. Leone and Reichstein's (2012) empirical result that grantbacks may reduce the speed of licensee innovation where both firms are familiar with the technology may be more relevant to our case of symmetric information, but also does not separate the analysis by innovation type As the model is stylised, it is difficult to fit it to specific cases[47]. Indeed, setting our paper alongside that of Choi (2002), the two taken together make a case for both empirical work and policy measures that break down the data and case treatment by innnovation type and informational setting. In his case, innovation type means quality; in ours, it means severability.

Finally, our analysis also contributes to the literature on sequential innovation. In particular, our results can be interpreted as showing that Green and Scotchmer's well-known conclusion that the

[47] To cite examples of this point, the Qualcomm case alluded to previously concerns severable innovations and the grantback was royalty free, but the licensee innovations appeared to have existed prior to the *BT* license, so the license could not have influenced innovation incentives. International Nickel Company, Inc, (INCO) v. Ford Motor Company and Caswell Motor Company, Inc., 166 F. Supp. 551; 1958 U.S. Dist. LEXIS 3578; 119 U.S.P.Q. (BNA) 72; 1958 Trade Cas. (CCH) P69,169 involved anticompetitive concerns for a royalty free grantback restricted to non-severable improvements in contrast to our expectation; however the licensor in the case was not a producer, and the licensee network was very wide and included in the grantback. As such, the grantback acted like a sharing system among a wide set of firms.

“vertical” scope of patent protection should be large enough to catch improvements is not robust to the introduction of a commonly observed patent clause, the grantback, as long as the second firm’s ability to innovate is sufficiently enhanced by the fact that it receives a licence to practice the basic technology. Where most learning occurs via the license, the license contract design is a better instrument than the patent design to allocate gains from the sequential innovation path. Our extension to uncertain severability at the time of innovation reinforces this interplay, indicating that the desirability of grantbacks as a tool for optimally incentivising innovation depends on patent scope: where patents are narrow so that initial patent holders readily lose control of follow-on technology, grantbacks peform better precisely because they promote technology sharing by providing insurance to the initial patent holder in the case of leapfrogging.

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Appendix 1: Non-Severable innovation with and without grantback

We first consider the case where the parties agree to a licensing contract without grantback. If firm *l* gets a license and innovates, then it would license the resulting improvement, *IT*, back to firm *L* for royalty r_2, which is determined by the following Nash Bargaining Solution :

$$\max_{r_2}[(1+\theta+r_1-r_2)-(1+r_1)][(1+\theta-r_1+r_2)-(1+\theta-r_1)] \quad \text{(A1)}$$

$$\leftrightarrow \max_{r_2}(\theta-r_2)r_2$$

The first term is the difference between firm *L*'s the pay-off when it pays to access *IT* and when it does not. Because *IT* is non-severable in this case, firm *l* owes royalty r_1 to firm *L* even if firm l innovates *IT*. The second term is the difference between firm *l*'s pay-off with and without licensing of *IT* and boils down to the royalty paid by *L* to access *IT*. The royalty rate that results from this bargaining is:

$$r_2^{NN} = \frac{\theta}{2} \quad \text{(A2)}$$

where we designate the case of no grantback and non-severable innovation by "*NN*". Not surprisingly, the two firms split the additional surplus created by the licensing agreement equally. Overall then, the additional profit that firm *l* gets if it innovates comes from two sources. Firstly, firm *l* can charge a price equal to $1+\theta$ instead of 1 in its home market. Secondly, firm *l* gets the royalty payment from firm *L*.

Firm l will therefore decide to invest in innovation as long as:

$$F \le \frac{3\theta}{2} \quad \text{(A3)}$$

Since the innovation is socially beneficial as long as $F \le 2\theta$, incentives to innovate are socially insufficient. This is simply the result of the parties' inability to sign a contract conditional on the realisation of the innovation before firm *l* must invest.

Assuming that the condition for innovation is satisfied, we move back to Stage 2, where the royalty, r_1, that *l* pays to get access to *BT* is the solution to the following problem:

$$\max_{r_1}[(1+\theta+r_1-r_2^{NN}))-\pi_L^R][(1+\theta-r_1+r_2^{NN}-\mathrm{F})-\pi_l^R] \quad \text{(A4)}$$

where $\pi_L^R = 2-c$ and $\pi_l^R = 0$ represent the profits of firms *L* and *l* when no agreement is reached so that firm *L* serves both markets (recalling that *c≤1*). Solving this bargaining problem, we get:

$$r_1^{NN} = 1 + \frac{\theta}{2} - \frac{c+F}{2} \tag{A5}$$

Hence, firm *L* earns a net royalty equal to $r_1^{NN} - r_2^{NN} = 1 - \frac{c+F}{2}$. Using the expressions in (A4) for the two firms' profits and the net royalty we therefore find that the equilibrium profits are $\pi_L^{NN} = 2 + \theta - \frac{c+F}{2} > \pi_L^R = 2 - c$ and $\pi_l^{NN} = \theta + \frac{c-F}{2} > 0$ so that, when the cost of innovation is low enough that the licensee would engage in further innovation, firm *L* is better off if it decides to license its technology to firm *l*.

Where a grantback is present, r_2 is not relevant. Assuming that firm *l* would innovate, the bargaining problem at stage 2 is:

$$\max_{r_1}[(1 + \theta + r_1) - (2 - c)](1 + \theta - r_1 - \mathrm{F}) \tag{A6}$$

so that:

$$r_1^{NG} = 1 - \frac{(c+F)}{2} \tag{A7}$$

where the superscript "*NG*" represents the case of a non-severable innovation with a grantback. Note that this royalty is equivalent to the *net* royalty earned by firm *L* without grantbacks. This of course means that the profits of firms *L* and *l* are exactly the same as for a license without a grantback clause. If $F > \theta$, there is no follow-on innovation and the pay-offs are obtained by setting $\theta = F = 0$. This completes a derivation of all the expressions in Table 1. The argument for propositions 1 and 2, given these expressions, is contained in the main text.

Appendix 2: Severable innovation and no grantback

Derivation of Figure 1: Assume that firm *I* innovates but that *IT* is not licensed back to firm *L*. Firm *I* can charge the full price equal to $1+\theta$ in its home market since firm *L* is still constrained by the territorial restraints in the first agreement.

Whether firm *I* or firm *L* serves the home market of firm *L* depends on the size of the follow-on innovation. If $\theta > c$, then the innovation advantage of firm *I* is larger than trade barriers so that firm *I* prevails and charges a price equal to $\theta - c$. If $\theta \leq c$, then firm *L* serves the market at a price equal to $c - \theta \geq 0$ [48].

By contrast, licensing the follow-on innovation back to *L* with a contract that includes territorial limits allows both firms to charge $1+\theta$ in their home market, with *L* transferring a royalty r_2 to firm *I*. For a large enough innovation ($\theta > c$), the royalty rate paid by *L* is determined by:

$$Max_{r_2}[1+\theta+r_2-(1+\theta+\theta-c)][1+\theta-r_2] \qquad \text{(A8)}$$

So that

$$r_2^{SN} = \theta + \frac{1-c}{2} \qquad \text{(A9)}$$

Where "*SN*" represents the case of a severable innovation and no grantback. The first term in square brackets of the maximisation problem represents Firm *I*'s comparison of earning the full price in its home market plus royalty revenues from Firm *L*'s market versus earning the full price in its home market but the margin it could earn abroad selling its own improvement but incurring both the transportation cost and the competitive constraint of a value of 1 from *BT*. The second term in square brackets is firm *L*'s benefit from selling at full price at home but paying royalty fees for the improvement compared to the alternative of earning zero, where *BT* competes disadvantagenously against the improved product. It is readily shown that we obtain the same royalty and the same pay-

[48] Firm *I* operates under territorial restraints if it wishes to use *BT*, so the only way to enter firm *L*'s market is to use *IT.* If the price of *IT* equals *c*, then firm *I* just breaks even selling *IT* in firm *L'*s home market. With this "minimum" price, however, consumers earn $1+\theta-c$ from *IT,* and 1 net of the price of *BT* if they purchase from firm *L.* Consumers have the option to buy either technology at the corresponding price, so firm *I* may "limit price" at $\theta - c$ and still capture the home market of firm *L*.

offs if $\theta < c$[49]. This leaves the firms with the following profits:

$$\pi_l^{SN} = 2\theta + \frac{3}{2} - \frac{c}{2} > 1 + 2\theta - c \tag{A10}$$

$$\pi_L^{SN} = \frac{1+c}{2} > 0 \tag{A11}$$

Since the licensing profits are higher than those obtained when the new technology is not licensed, we conclude that the follow-on innovation is made available to both firms.

Follow-on innovation arises if it is profitable for firm *l*, i.e if

$$1 - r_1 \leq 2\theta + \frac{3}{2} - \frac{c}{2} - F \leftrightarrow \frac{1}{2} + 2\theta - \frac{c}{2} + r_1 \geq F \tag{A12}$$

Importantly, notice that, since innovation means that firm *l* does not need to pay any royalty to the owner of the basic technology, firm *L*, firm *l* sees these royalty "savings" as an additional benefit of innovating. Hence, there is a threshold value of r_1 above which follow-on innovation occurs as a means to "escape" these onerous royalty payments.

We can now move back to the second stage of the game where, having agreed to negotiate a licensing agreement, the owner of *BT* and the potential licensee agree on a royalty rate r_1. Without licensing, the *BT*-owner gets *2-c*. Under our assumption that $c < 1$, this profit is higher than firm *L*'s profits if firm *l* innovates. Hence firm *L* would always prefer to retain control of *BT* to the alternative of reaching an agreement with a royalty high enough to trigger follow-on innovation. We can therefore describe the negotiation as the choice of a royalty payment that is low enough to avoid triggering follow-on innovation, i.e:

$$Max_{r_1}[1 - r_1][1 + r_1 - (2 - c)]$$

$$\text{s.t. } r_1 \leq F + \frac{c-1}{2} - 2\theta \equiv r_1^{lim} \tag{A13}$$

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49 $Max_{r_2}[1 + \theta + r_2 - (1 + \theta) - (\theta - c)][1 + \theta - r_2]$, so that $r_2 = \theta + \frac{1-c}{2}$

The interior solution of this maximisation problem is:

$$r_1^* \ = 1 - \frac{c}{2} \tag{A14}$$

If there is no interior solution, the royalty rate is defined by the constraint, which we will label r_1^{lim} when licensing occurs. This is the negatively sloped constraint in Figure 1, whereas the optimal royalty is defined by a horizontal line, and depending on the cost of serving an external market.

Moving on to the details of the ranges of innovation efficiency that distinguish the three panels of Figure 1, there is follow-on innovation if

$$F \leq \frac{1-c}{2} + 2\theta + r_1 \tag{A15}$$

Assuming that there is no innovation, the bargaining between the parties is represented as

$$Max_{r_1}[1 - r_1][1 + r_1 - (2 - c)] \tag{A16}$$

So that

$$r_1^* = 1 - \frac{c}{2} \tag{A17}$$

The vertical intercept of the improvement constraint in Figure 1 is

$$r_1^{INT} = F - \frac{1-c}{2} \tag{A18}$$

This is larger than r_1^* if $F > \frac{3}{2} - c$. So, if that condition is satisfied, there is a range of values of θ for which r_1^* is the agreed upon royalty. This range is from 0 to the value of θ for which the improvement constraint just binds at $r_1 = r_1^*$, i.e. up to

$$\theta = \frac{F}{2} + \frac{c}{2} - \frac{3}{4} \tag{A19}$$

For larger values of θ, the equilibrium royalty is the highest royalty that does not trigger innovation, as long as this royalty leaves the licensor at least as well off a without licensing, i.e.

$$r_1 = F - \frac{1-c}{2} - 2\theta \tag{A20}$$

as long as $1 + r_1 \geq 2 - c$, i.e. as long as

$$\theta \leq \frac{F}{2} + \frac{3}{4}(c-1). \tag{A21}$$

If $F \leq \frac{3}{2} - c$, then there is still a range where licensing occurs but at a royalty below r_1^* as long as the vertical intercept of the improvement constraint is higher than the minimum royalty that the licensor needs to make licensing worthwhile, i.e.

$$r_1^{INT} = F - \frac{1-c}{2} > 1 - c \leftrightarrow F > \frac{3}{2}(1-c) \tag{A22}$$

The result can be stated as:

Lemma 1: *For severable innovation, the basic technology is licensed under the following conditions and with the following royalty rates*:

$$If\ \ F > \frac{3}{2} - c\ \ then\ \ r_1 = r_1^*\ \ for\ \ \theta \leq \frac{F}{2} + \frac{c}{2} - \frac{3}{4}.$$

$$r_1 = r_1^{Lim}\ \ if\ \ \frac{F}{2} + \frac{c}{2} - \frac{3}{4} < \theta \leq \frac{F}{2} + \frac{3}{4}(c-1)$$

$$If\ \ \frac{3}{2}(1-c) < F \leq \frac{3}{2} - c\ \ then\ \ \ r_1 = r_1^{lim}\ \ for\ \ \theta \leq \frac{F}{2} + \frac{3}{4}(c-1).$$

This concludes the argument for the expressions underlying Figure 1, with the three ranges of Lemma 1 corresponding to Figures 1a, 1b, and 1c, respectively.

Appendix 3: Severable innovation and grantback

We superimpose in the graphs below firm *l*'s "improvement line" on firm *L*'s preferences, which are represented by regions defined by a horizontal line that determines whether licensing without innovation is preferred to no licensing $1{+}r_1 \gtrless 2-c$; a vertical line determining whether licensing with innovation is preferred to no licensing $1+\theta \gtrless 2-c$; and a $45°$ diagonal line determining whether licensing without innovation is preferred to licensing with innovation $1+r_1 \gtrless 1+\theta$. As in the text, the improvement line says that firm *l* innovates if:

$$1+\ \theta - F\ \ \geq 1 - r_1 \leftrightarrow\ \ r_1\ \ \geq F - \theta \tag{A23}$$

so that the "improvement" line reflecting the licensee's indifference between innovating or not has an intercept equal to *F* and a slope of -1 in the space of (θ, r_1). We must now consider three cases, depending on where this line is located.

We begin with parameter ranges where innovation costs are low, i.e. $F < 1-c$. This case is shown in Figure 3.a.

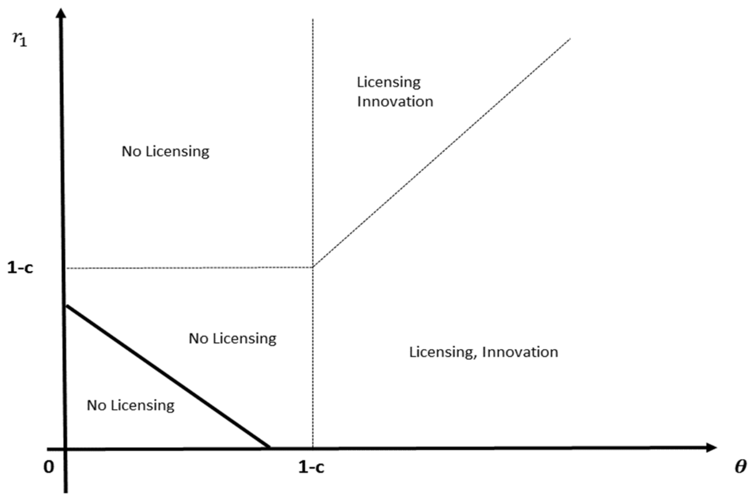

Figure 3.a. Firm *L*'s Preferred Feasible Outcomes, Low Innovation Cost, Grantback

We see that the two "licensing regions" lie fully above the "improvement line", so that where licensing occurs, it always leads to innovation. Firm *L* must, therefore, compare the payoff to licensing, equal to $1+\theta$, to not licensing and getting a payoff equal to *2*-c. Licensing is preferred as long as the innovation is significant enough ($\theta \geq 1-c$) and licensing occurs at a non-negative royalty rate. The size of the royalty is irrelevant to our discussion as it will not be paid when improvement occurs whilst improvement occurs for any non-negative royalty. If this inequality is reversed the equilibrium of the game is straightforward: no licensing occurs. We state these preferences and innovation outcomes in the text of Figure 3a.

Now consider higher ranges of *F.* Here, we need to consider the royalty rate, as licensing without innovation may well occur. The reasoning is the same as in Appendix 2. The only difference is that the improvement constraint is now given by

$$F \leq \theta + r_1 \tag{A24}$$

So that $r_1^{INT} = F$. Hence if $F \geq r_1^*$, there is a range of values of θ for which r_1^* is the agreed upon royalty. This range is from 0 to the value of θ for which the improvement constraint just binds at $r_1 = r_1^*$, i.e. up to

$$\theta = F + \frac{c}{2} - 1. \tag{A25}$$

For larger values of θ, the equilibrium royalty is the highest royalty that does not trigger innovation, as long as this royalty leaves the licensor at least as well off a without licensing, i.e.

$$r_1^{Glim} = F - \theta \tag{A26}$$

as long as $1 + r_1 \geq 2 - c$, i.e. as long as

$$\theta \leq F + c - 1. \tag{A27}$$

If $F \leq r_1^*$, then there is still a range where licensing occurs but at a royalty below r_1^* as long as the vertical intercept of the improvement constraint is higher than the minimum royalty that the licensor needs to make licensing worthwhile, i.e.

$$F > 1 - c \tag{A28}$$

Over this range we have:

$$r_1 = r_1^{Glim} = F - \theta. \tag{A29}$$

The case of $1 - c < F \leq 2(1 - c)$ is treated in the text surrounding Figure 3. Here, the intercept of the negatively sloped "improvement line" is above the horizontal line $r_1 = 1 - c$ but the entire line falls below the intersection of the lines $r_1 = 1 - c$ and $r_1 = \theta$. Compared to Figure 3a, we observe a range of parameters for which the patent-holder prefers licensing without innovation, so that the royalty rates we have just discussed affect the earnings in the equilibrium outcome. Furthermore, the range for which licensing with innovation is preferred to no licensing shrinks by the area of the triangle of base $(1 - c, F)$. In this area, the follow-on innovation is not valuable enough to warrant the investment by firm l at the agreed royalty rate. At the same time, the royalty on *BT* is too small to make licensing without innovation worthwhile for firm *L.*

Finally, we illustrate in Figure 3.c: the case where if the cost of innovation is high enough, $F > 2(1 - c)$ so that the innovation line lies above the point (1-*c*, 1-*c*). Hence, the pattern remains rather similar to the case in the text: the range where licensing that does not trigger innovation is preferred expands, while the range where licensing with innovation is preferred keeps shrinking. As in the text, "LNI" refers to licensing with no innovation.

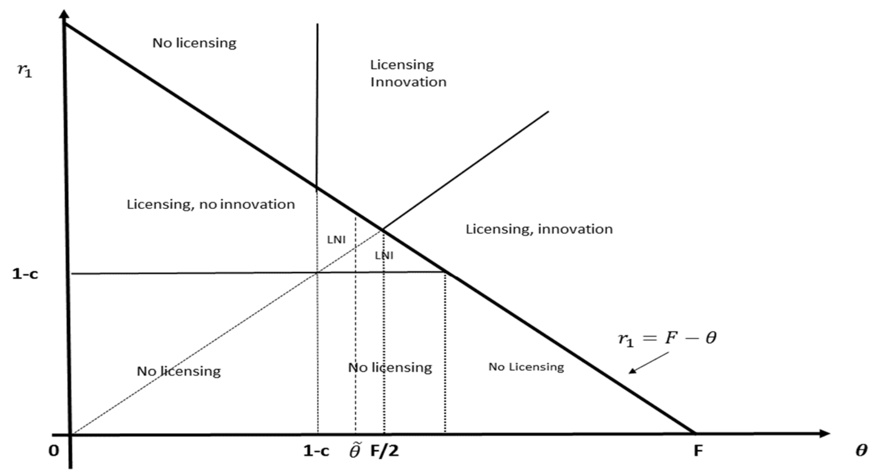

Figure 3.c. Firm *L*'s Preferred Feasible Outcomes, Inefficient Innovation, Grantback

Lemma 3 follows directly from Figures 3 and 3c, and describes in detail the region for which licensing but no innovation occurs:

Lemma 3: *Suppose that the innovation is severable and there is a grantback clause. Over the range* $\theta \in [0, F-1+c]$*, licensing without innovation occurs at the following royalty rates:*

$$If\ \ F > 1-\frac{c}{2}\ \ and\ \ \theta \leq F+\frac{c}{2}-1\ \ then\ \ r_1 = r_1^* = 1-\frac{c}{2}$$

$$If\ \ F > 1-\frac{c}{2} and\ \ F+\frac{c}{2}-1 < \theta \leq F+c-1\ \ then\ \ r_1 = r_1^{max} \equiv F-\theta$$

$$If\ \ 1-c < F \leq 1-\frac{c}{2}\ \ and\ \ \theta \leq F+c-1, then\ \ r_1 = r_1^{max} \equiv F-\theta$$

The argument is as follows. If the optimal royalty, r_1^*, falls below the intercept (*F*) of the diagonal "improvement" line and at the same time the associated size of the improvement (θ) is such that firm *l* would not want to innovate, then the optimal royalty is charged, and *BT* is licensed but no innovation follows. This "threshold" size of improvement is indicated by $\bar{\theta}$ in Figure 3 of the text. If it is the case that the royalty falls below the intercept, *F*, but at values of the improvement such that follow-on innovation would normally occur, $\theta \geq \bar{\theta}$, the royalty for *BT* must be capped at $F-\theta$ for follow-on innovation not to occur under *BT* licensing. If the royalty exceeds this, firm *l* has a large enough incentive to innovate in order to escape the royalty that innovation will surely follow *BT* licensing. Finally, if the optimal royalty is above the intercept, *F*, but the size of the improvement is small enough that a capped royalty would induce firm l not to innovate, then the royalty is similarly capped at $F-\theta$ and *BT* licensing occurs.

For values of θ above $\bar{\theta}$, but still to the left of *1-c*, the basic technology does not get licensed. As soon as $\theta \geq 1-c$, the two options are no licensing and licensing at a royalty which is high enough to trigger follow-on innovation. Both parties are better off with licensing so licensing occurs at a rate which is sufficiently high to lie above the "improvement" line. Since this royalty is never paid in our stylised framework, its precise amount is of no relevance to our further discussion.

If follow-on innovation is very inefficient ($F > 2(1-c)$), we find ourselves in the type of situation described in Figure 3.c. Just to the right of $\theta = 1-c$, there is now a range $\theta \in]1-c, F-1+c[$, where three outcomes are feasible depending on the size of r_1: no licensing, licensing at a rate that does not trigger follow-on innovation and licensing at a rate that is high enough to trigger follow-on innovation. Because we are to the right of $\theta = 1-c$, firm *L* prefers licensing with innovation to no licensing as long as the royalty exceeds 1-c. As the potential licensee also prefers licensing, the *BT* is licensed over this range at some royalty rate, r_1.

Consider a value of θ in this range, such as $\tilde{\theta}$. As long as the royalty is such that $r_1 < \theta$, firm *L* prefers licensing with innovation to licensing without innovation since it earns $1 + \theta$ with the grantback and $1 + r_1$ without follow-on innovation. If the royalty were set high enough to trigger innovation, however, the royalty would also have to be such that $r_1 > \theta$, where firm *L* would prefer no improvement to follow-on innovation. Both parties, therefore, agree on a level of royalty which does not trigger innovation, i.e. a royalty in the interval $[\theta, F - \theta]$. For even larger values of θ, both parties agree to license at a royalty which is large enough to trigger innovation since royalties can be found on or above the "improvement line" and also below the line $r_1 = \theta$, where firm *L* also prefers licensing with innovation.

Appendix 4: Uncertain innovation type

Proposition 6: *Consider the effect of reducing the cost of innovation* F i*n the absence of grantback. Assume that there are no barriers to trade. For all levels of s, the probability of severability, there is licensing with no innovation (LN) for high values of F, followed by no licensing (N). As long as the innovative step* θ *is sufficiently small and licensing without innovation followed by no licensing followed by licensing with innovation is the innovative step is sufficiently large. If the probability that the innovation would be non-severable (infringing) is high enough (*$s < \frac{1}{3}$*), there is a further range, for a sufficiently high inventive step, where licensing without innovation is directly followed by licensing with innovation as the cost of innovation decreases.*

Proof: Define F_1 as the innovation cost equating π_L^{LN} and π_L^{LI}, where these are the profits of the licensor to licensing without and will follow-on innovation, respectively, F_2 as the innovation cost making the licensor indifferent between licensing with no innovation or not licensing at all (π_L^N), and F_3 the innovation cost making the licensor indifferent between licensing with innovation or not licensing at all. F_0 is defined such that we just meet incentive compatibility constraint that the licensee innovates whilst holding the license terms to the individual rationality constraint, such that the licensee accepts a license.

Let us begin with the extreme cases. If $s = 0$ then $F_o = \frac{3\theta}{2}$, $F_1 = 2\theta$, $\pi_L^{LN} = 2, \pi_L^N = 2 - c$. For $F \leq F_o$. Innovation is triggered as long as the individual rationality constraint of the licensee is satisfied, i.e. as long as $r_1 \leq 1 + \frac{3\theta}{2} - F$. Charging the highest possible royalty and paying the royalty for the follow-on innovation, the licensor gets $\pi_L^{LI} = 2(1 + \theta) - F$. For $F > F_o$ the incentive compatibility constraint (ie, the condition that generates innovation by the licensee) is violated so there can be no innovation. Hence, since $2 \geq 2 - c \ \forall c$, the basic technology is licensed but there is no innovation. For lower innovation costs licensing with innovation dominates.

We now turn to the special case where the innovation is severable for sure, i.e. $s = 1$. We have $F_o = 1 + 2\theta + \frac{1-c}{2}$. The individual rationality constraint with innovation is $F \leq F_o$. As before, there is licensing without innovation for all $F > F_0$. We also have $F_1 = \frac{1+c}{4} + \frac{3\theta}{2}$, $F_2 = 1 + 2\theta - \frac{3c-1}{2}$ and $F_3 = c + \theta - 1$. Think of these constraints in a graph with F on the vertical axis and θ on the horizontal axis. We have $F_3(\theta = 0) < F_1(\theta = 0) < F_2(\theta = 0) \leq F_o(0)$. Moreover $F_2(\theta)$ is steeper than $F_1(\theta)$, which is itself steeper than $F_3(\theta)$. This gives us our equilibrium configuration. Note that, for $c + \theta < 1$ there is no range with innovation.

We now move to the general case. We have $F_o \equiv s + \frac{\theta(3+s)+s(1-c)}{2}$, $F_2 = \frac{3s(1-c)+(s+3)\theta}{2}$ and $F_3 = (c - s) + (2 - s)\theta$. For F_2 and F_3 to be relevant they must lie below F_o. F_2 is always lower than F_o. Next we establish there is a positive value $F = F_1$ below which the licensor prefers to license with innovation than without it. This follows `directly from the fact that profits with licensing but no innovation are increasing in *F* while the profits with innovation are decreasing in *F* and the fact that, for $F = 0$, $\pi_L^{LN} = 1 - \frac{s+3}{2s}\ \theta - \frac{1-c}{2} < \pi_L^{LI} = (2 - s)(1 + \theta)$. It follows that the equilibrium pattern only depends on the relative ranking of F_2 and F_3. If $F_2 > F_3$, then we go from licensing without innovation to no licensing to licensing with innovation as the cost of innovation decreases. If $F_3 \geq F_2$, then we go directly from licensing without innovation to licensing with innovation. Ranking these two critical values of the cost of innovation, we get that, while F_2 is always positive, $F_3 \geq 0 \leftrightarrow \theta \geq s \leq \frac{2\theta+c}{1+\theta} \equiv s^*$. We also get $F_3 \geq F_2 \leftrightarrow s \leq \frac{\theta+2c}{3(1-c)+3\theta+2} \equiv s^{**}$. Assume first that $c = 0$. At $\theta = 0$, we have $s^* = s^{**} = 0$. We also have $s^* > s^{**} \forall\ \theta$ and both s^* and s^{**} are increasing in θ. We also have $s^* = 1$ for $\theta = 1 - c$ and $\lim_{\theta \to \infty} s^{**} = \frac{1}{3}$. Notice also that increasing *c* from zero shifts both s^* and s^{**} profiles upwards but shifts s^{**} more than s^*.

Proposition 7: *In the absence of grantback, there is a range of innovation fees for which there is socially excessive innovation if and only if* $s < \frac{c}{1+\theta}$ *and* $s > \frac{2\theta+c}{3(1-c)+3\theta+2}$. *This range exists only if trade barriers are high enough and if the innovative step is not too large. There can also be excessive innovation if* $s < \frac{2\theta+c}{3(1-c)+3\theta+2}$ *and* $s > \frac{\theta}{3+\theta-c}$. *There cannot be excessive innovation for either of the extreme cases where* $s = 0$ *or* $s = 1$.

Proof: For $s \in [s^{**}, s^*]$ licensing with innovation occurs for all $F \leq F_3$. Over this range, $c - s^* + (2 - s^*)\theta \leq F_3 \leq c - s^{**} + (2 - s^{**})\theta$.

We now check whether there can be socially excessive innovation. $F_3 \geq 2\theta \leftrightarrow (c - s) + (2 - s)\theta \geq 2\theta \leftrightarrow s \leq \frac{c}{1+\theta}$. $s^{**} \leq \frac{c}{1+\theta} \leftrightarrow there\ is\ a\ range\ of\ excess\ innovation\ iff\ \frac{c}{1+\theta} \geq \frac{2\theta+c}{3(1-c)+3\theta+2} \leftrightarrow c(4 - 3c) + 2\theta(c - 1 - \theta) \geq 0$. Hence $\exists\ \theta_o > c\ st\ s^{**} \leq \frac{c}{1+\theta} \forall\ \theta < \theta_o$. This means, that, for $\theta < \theta_o$, there is a range of values of $F > 2\theta$ for which there is excessive innovation. Notice also that we can only have such a range for high enough barriers to trade.

For $s \in [0, s^{**}]$, licensing with innovation occurs for $F \leq Min[F_o, F_1]$. If s is close enough to s^{**} then, by continuity there will also be a value of θ above which there is a range of innovation costs for which there is excessive innovation. However we have $\frac{dF_o}{ds} > 0, \frac{dF_1}{ds} < 0 \;\; \forall \;\; s \leq s^{**}$, $F_o\;(s^{**}) > F_1(s^{**})$ and $\lim_{s \downarrow 0}[F_o(s) - F_1(s)] < 0$. Hence $\exists \;\; s^o \;\; st \;\; F_o \leq F_1 \;\; \forall \;\; s \leq s^o$. Since $F_o(0) = \frac{3\theta}{2} < 2\theta$ this implies that the range of excessive innovation vanishes for low enough values of *s*. In particular there cannot be excessive innovation if $s = 0$ or $c = 0$.

Proposition 8: *Consider the effect of progressively decreasing the cost of innovation with grantback. For* $s > \frac{\theta+c}{1-c}$ *we go from licensing with no innovation (LN) to no licensing (N) to licensing with innovation (LI) , while for* $s \leq \frac{\theta+c}{1-c}$ *we go from LN directly to LI. For* $s > \theta$, *there are values of F for which there is socially excessive innovation (*$F > 2\theta$*). Excessive innovation cannot occur for* $s \leq \theta$. *There are values of F for which the incentives to innovate are insufficient iff* $s \leq \theta$.

Proof: Licensing without innovation is preferred to no licensing if

$$2 - c \leq 1 + \frac{F - \theta}{s} \leftrightarrow F \geq \theta + s(1 - c) \equiv F_2$$

Licensing with innovation is better than no licensing if

$$2(1 + \theta) - F \geq 2 - c \leftrightarrow F \leq 2\theta + c \equiv F_3$$

Licensing with innovation is preferred to licensing without innovation if

$$2(1 + \theta) - F \geq 1 + \frac{F - \theta}{s} \leftrightarrow F \leq \frac{s + (1 + 2s)\theta}{1 + s} \equiv F_1$$

$F_2 \leq F_o = s + \theta \;\; \forall \;\; s, c, \theta$ and $F_3 \geq 0 \;\; \forall \;\; \theta, c$. Therefore the pattern of licensing and innovation as *F* decreases depends only on the relative ranking of F_2 and F_3. We have $F_3 \geq F_2 \;\; \leftrightarrow s \leq \frac{\theta+c}{1-c}$. So for $s > \frac{\theta+c}{1-c}$ we go from LN to N to LI as the cost of innovation decreases, while for $s \leq \frac{\theta+c}{1-c}$ we go from LN directly to LI.

We now check whether incentives to innovate can be socially excessive. For $s > \frac{\theta+c}{1-c}$ $F_3 < F_2 < F_o$

and the maximum value of *F* for which there is innovation is $F = F_3 = 2\theta + c$ Hence, unless $c = 0$ there is always a range over which there is excessive innovation. If $s \leq \frac{\theta+c}{1-c}$ then the highest value of the cost of innovation for which there is innovation is $F = Min[F_1, F_o]$. $Min[F_1, F_o] = F_o \ iff \ \theta \geq s$. We then have two ranges. For $s \in [\theta, \frac{\theta+c}{1-c}]$, the maximum fee for which there is innovation is F_1. We have $F_1 > 2\theta \ \forall \ s > \theta$. Hence, over this range there are always values of *F* for which there is excessive innovation. For $s < \theta$, the maximum value of *F* for which there is innovation is $F_o = s + \theta < \theta$ so that there cannot be excessive innovation.

Finally we check for range where incentives to innovate are not sufficient, i.e. where there is no innovation in spite of the fact that $F < 2\theta$. If $F_2 > F_3$ then LN occurs for all $F \geq F_2$ so there is a range of *F* for which there is insufficient innovation if $F_2 < 2\theta \leftrightarrow s < \frac{\theta}{1-c}$ but this cannot occur since $F_2 > F_3 \rightarrow s > \frac{\theta+c}{1-c}$. If $F_3 > F_2$ then LN occurs for all $F > Min(F_o, F_1)$. For $s > \theta$ this min is $F_1 < 2\theta \ iff \ s < \theta$, which is not possible. For $s \leq \theta$ $Min(F_o, F_1) = F_o < 2\theta \ iff \ s < \theta$ so there must be a range of insufficient innovation.