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Sale versus licensing of a cost-reducing innovation by an outside patentholder

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A B S T R A C T

We investigate an outside patentholder's choice between selling and licensing a cost-reducing innovation to firms that produce differentiated goods in a Cournot duopoly. Sale implies the transfer of ownership rights, whereas licensing—by the patentholder directly or by any assignee—occurs through an endogenously chosen two-part tariff contract. We find that the patentholder has an incentive to sell the innovation (to a single firm that, in turn, licences it to its competitor) only when the goods are close substitutes and the innovation size is sufficiently minimal. Otherwise, the patentholder prefers to licence the innovation to both firms. Although the transfer of innovation, whether through outright sale or licensing, always improves aggregate welfare compared with the pre-transfer scenario, consumer surplus is reduced when the transfer is made by means of sales. Therefore, a socially optimal public policy should aim at banning the sale of outside innovations or, at least, preventing their subsequent licensing by the assignee from within the industry.

1. Introduction

External exploitation of technological assets is a growing phenomenon, with intellectual property (IP) transactions increasing substantially in number and volume (Jeong et al., 2013). In this respect, patent licensing is a key avenue for patentholders that do not produce the good embedded in the patented innovation to generate a revenue stream from their IP. As one example, Qualcomm developed the Code Division Multiple Access technology for use in cellular phones but does not provide the corresponding wireless services. Therefore, as an outside patentholder, Qualcomm developed wireless (3G, 4G and 5G) communication patents are licensed to smartphone manufacturers and wireless service providers such as Verizon and Sprint (Mock, 2005). Another salient example is Arm (ARM Holdings), a British semiconductor and software design company of processor architectures (CPU, GPU, etc.) and related technology but does not manufacture its own physical chips. Therefore, Arm transfers its semiconductor IP cores to a wide network of firms (including Apple, Samsung, Nvidia and Google) that take the designs, sometimes modify them, and manufacture the final silicon chips through foundries like Taiwan Semiconductor Manufacturing Company. This enables Arm, as an outside IP and patent provider[1] in the semiconductor space, to collect royalties on chips produced with its designs.[2]

Licensing is also a fairly common practice for inside patentholders, i. e. incumbent innovative firms with the capacity to exploit their technology themselves to manufacture a product. Retaining ownership of their patented technology, such firms commercialise it externally by granting direct competitors the right to use it, generating additional revenue streams. Empirical evidence has demonstrated that it is common practice for producing patentholders not only implement their innovations themselves but also licence them to direct rivals in the marketplace (Jiang and Shi, 2018). Two salient examples of this strategy are General Motors Co. and Microsoft. In 2000, General Motors licensed its OnStar satellite-based mapping service technology to carmakers such as Honda Motor, Audi, Isuzu, Subaru and Volkswagen, which are direct competitors (Montinaro et al., 2020).[3] Likewise, Microsoft successfully licensed its patents related to the Android operating system to various

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[1] In the business context, 'patent provider' describes an entity (which is also a patent owner) whose business model revolves around licensing its patented technology to others, essentially "providing" access to its IP assets.

[2] See https://www.theverge.com/23373371/arm-chips-chip-shortage-ceo-rene-haas-tech-intel-apple-decoder.

[3] See https://global.honda/en/newsroom/worldnews/2000/c000524.html for more details.

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device manufacturers, including major companies such as Samsung and HTC, despite competing with them in the mobile market via its own Windows Phone platform.[4]

A substantial body of theoretical work has examined how patentholders of cost-reducing (process) innovations behave when monetising them, either as outside patentholders who licence the innovations to one or more firms in the marketplace or as inside patentholders who exploit the innovations themselves while also licensing them to direct competitors in the marketplace. In particular, the literature has overwhelmingly discussed patent licensing in the context of quantity competition with full information and full knowledge diffusion; e.g. see Sen and Tauman (2007), San Martín and Saracho (2010, 2016), Poddar and Sinha (2010), Wang (2002), Erkal (2005), Li and Song (2009), Li and Yanagawa (2011) and Bagchi and Mukherjee (2014).[5] Considering different contractual schemes (fixed-fee payments, per-unit royalties, ad-valorem royalties and two-part tariff (2PT) contracts shaped as a fixed-fee payment combined with a royalty component) attention has focused on determining the optimality and welfare impact of particular licensing schemes in different modelled scenarios. In most extant studies, under varying degrees of generality, the (inside or outside) patentholder finds it optimal to include some type of royalty when licensing an innovation.[6]

However, an alternative channel for an outside patentholder to profit from its IP is to sell ownership rights outright to one or several potential buyers,[7] who, in turn, can potentially licence the usage rights to direct competitors in the product market (Odasso et al., 2014; Sinha, 2016; Banerjee and Poddar, 2019). In practice, licensing and outright sale are both used to commercialise innovations (Niu, 2019) and are the major alternatives in technology transactions (Chiesa et al., 2008; Jeong et al., 2013; Kirchberger and Pohl, 2016; Shen et al., 2018).[8] In this respect, with the spread of the open innovation paradigm, more patentholders are selling their technological know-how to maximise potential revenue returns (Bianchi et al., 2011). For example, a growing number of firms in Taiwan actively seek and purchase new patents to safely enter new markets and avoid any threat of patent litigation (Huang and Chang, 2011). Moreover, since 2004, the Taiwanese government-sponsored research organisation—the Industrial Technology Research Institute (ITRI)—has actively assisted foreign patentholders seeking to sell their patents to Taiwanese firms.[9] Likewise, Medtronic, a major medical device company, frequently acquires patents and technologies from independent inventors and startups as a core aspect of its innovation strategy. In January 2015, for example, it gained access to a wide range of surgical and medical patents by acquiring Covidien for 42.9 billion USD and subsequently went on to develop technologies that originated with Covidien, particularly in the areas of surgical staplers, energy-based devices and ventilators.[10]

Technology transfer through "sale" can also be understood as occurring in mergers and acquisitions (M&As). In a January–February 2019 survey of representatives of leading industrial firms, investment banks and investors conducted by A.T. Kearney (2019)—a top global management consulting firm—technology access was determined to be the primary driver of industrial M&As, over and above other issues such as consolidation within sectors, markets or a competitive environment. Noteworthy examples in 2018 mentioned by A.T. Kearney (2019) included acquisitions of Microsemi by Microchip, Cavium by Marvell and Siliconware Precision Industries by Advanced Semiconductor Engineering.[11] Along the same lines, the global law firm DLA Piper conducted a survey in 2020, concluding that the main motivation for acquiring external businesses is access to new technology.[12] Likewise, analysing 39,009 M&As by listed European firms over the 2001–2020 period, Fütterer et al. (2025) found that non-tech firms that actively managed their real options portfolios are more likely to engage in technology-motivated acquisitions.

Although patent sale has been investigated from an empirical perspective using data on patent auctions and patent re-assignments[13] (see Caviggioli et al., 2020, and the references therein), patent sale and the strategic choice between outright sale and licensing as alternative channels for (outside) IP transfer have not been the subject of much theoretical scholarly scrutiny, despite its relevance. In fact, several academic sources (see, e.g. Jeong et al., 2013; Banerjee and Poddar, 2019; Caviggioli et al., 2020) confirm that research into patent sales and the strategic decision between selling (assignment) and licensing has been less extensive compared to research on general licensing. A primary reason may be the difficulty in gathering reliable data on patent sales and the specific contractual terms involved. Unlike licensing deals, which often need to be officially recorded in some agencies (like with the United States Patent and Trademark Office for some formalities), the details of private patent sales are often confidential (Graham et al., 2018; Holgersson and van Santen, 2019; Caviggioli et al., 2020). Furthermore, a substantial body of research has historically focused on licensing as the primary monetization tool for inventions, particularly in the context of university technology transfer offices, which likely led to other forms of transfer receiving less attention (Holgersson and van Santen, 2019). Finally, it is also suggested that IP management has been treated in an overly simplistic manner, often assuming that valuable innovations should simply be patented, licensed, or spun off, without deep analysis of the sale option (Holgersson and van Santen, 2019).

Despite the historical gap, the strategic choice between patent selling and licensing is receiving more attention in contemporary research. For example, in the context of an outside innovator and symmetric potential innovation users that compete à la Cournot, Tauman and Weng (2012) found that innovation sale is strictly better than licensing—a significant result because of the alternative profit opportunity arising from outright

[4] See https://www.siliconrepublic.com/business/microsoft-to-get-android-royalties-from-samsung-in-patent-deal.

[5] Patent licensing has also been widely investigated under other product market configurations, namely, Bertrand competition (Muto, 1993; Bagchi and Mukherjee, 2014; Colombo and Filipini, 2015), Stackelberg competition (Kabiraj, 2004; Li and Yanagawa, 2011; Antelo and Bru, 2022, 2024) and spatial competition (Poddar and Sinha, 2004; Lu and Poddar, 2014; Banerjee and Poddar, 2019), among others.

[6] Including a per-unit or ad-valorem royalty in licensing agreements has also been empirically observed (Macho-Stadler et al., 1996; Bousquet et al., 1998; Lim and Veugelers, 2003; Trombini and Comacchio, 2012).

[7] In addition to licensing, on typical patent broker websites, sale is proposed as a common patent trading mode (e.g. https://avonriverventures.com/sell-patents/). Indeed, patent sale is commonly used by modern high-tech industries (Serrano, 2010; Odasso et al., 2014). Beyond licensing and sale, other channels for patentholders to transfer their IP include mergers and acquisitions, partnerships agreements and spin-offs (Caviggioli et al., 2020).

[8] Jeong et al. (2013) found a strongly substitutive relationship between licensing and sale wherein firms in technology markets tend to prefer licensing when uncertainty is low or transaction costs are high; otherwise, they tend to prefer sale.

[9] Key proposals include patent sale in the right technical area, providing supporting materials to highlight patent value, providing accurate encumbrance information and using a local broker to overcome the obstacles of understanding and navigating Taiwan's market (Huang and Chang, 2011).

[10] A 1.35 billion USD agreement in 2005 with Dr. Gary K. Michelson, an independent surgeon turned inventor, granted Medtronic ownership of numerous patents related to spinal surgery technologies and rights to future spine-related inventions by Dr. Michelson for 15 years. See https://www.nytimes.com/2005/04/23/business/medtronic-to-pay-135-billion-to-inventor.html#:~:text=LOS%20ANGELES%2C%20April%2022 %20 %2D%20Medtronic,medical%20 foundation%20he%20is%20starting.

[11] See https://www.i-scoop.eu/technology-access-merger-acquisition-driver-report/and https://www.kearney.com/.

[12] See https://www.dlapiper.com/en/insights/publications/tech-index/tech-index-2022/ma.

[13] The sale of IP rights is legally referred to as 'assignment', with the seller as the 'assignor' and the purchaser as the 'assignee'.

sale rather than licensing. Considering an outside patentholder's technology transfer by means of sale or licensing in a spatial framework when potential users are asymmetric, Banerjee and Poddar (2019) found that, irrespective of the innovation size (i.e. drastic or non-drastic) or the degree of cost asymmetry between users, the patentholder is always better off selling the innovation to a firm that further licences it to a rival in the market. Similarly, examining how an outside patentholder transfers an innovation to potential users that produce a homogeneous good in a Cournot setting with ex-ante asymmetric costs of production, Sinha (2016) demonstrated that the patentholder can optimise the innovation's value by selling it for a fixed-fee payment to an efficient firm that, as the new owner, licences it to a rival in the product market.

In the context of a vertically related market and an innovation that reduces the costs of producing an input, technology sale can also be used as an outsourcing strategy. Assuming Cournot competition in the product market, Kabiraj and Sinha (2014) found that, although a market competitor holds the lowest cost technology to produce the input, it may sell that technology to an independent input supplier and buy the input at a higher price instead of producing it in-house at a lower cost. Technology sale, which functions as a commitment, occurs when the initial technological gap between input producing firms is small. This analysis is extended by Kabiraj and Sinha (2016) to a differentiated Bertrand duopoly in which one innovative firm owns an input production technology superior to that of an existing input supplier. If the degree of product differentiation is low or the efficiency gap between in-house input production and input production by the outside supplier is not large, the innovative firm will sell its superior technology and outsource the input from the input supplier.

In summary, the choice between patent sale, which entails ownership transfer that enables the assignee, as new owner, to further licence to one or more direct competitors in the marketplace, and patent licensing, which entails ownership retention while allowing one or more producers to use the innovation, is a relevant concern that requires closer attention (Banerjee and Poddar, 2019). In this regard, the first aim of this study is to determine whether an outside patentholder with a cost-reducing innovation prefers to sell it in return for an agreed price or licence it by means of a specific agreement. The second aim is to ascertain whether outright sale or licensing generates higher welfare for consumers and society at large, to understand the extent to which the patentholder's private incentives are aligned with social incentives and, if not aligned, to draw policymaking lessons regarding socially optimal IP transfer methods from non-producing patentholders.

To investigate these issues, we examine an outside patentholder's incentives to sell or licence a cost-reducing innovation, focusing on which arrangement arises endogenously. The innovation is applicable in a horizontally differentiated duopolistic industry in which producers compete by setting quantities and have a potential interest in using the new, more efficient technology. Outright sale implies that the innovation purchaser becomes a potential inside licensor. In contrast, licensing by the patentholder or the innovation purchaser involves granting the licensee(s) the rights to use the innovation and is assumed to be made through (endogenously chosen) 2PT contracts based on a fixed-fee combined with per-unit or ad-valorem royalty.

In this context, our first finding shows that innovation size, i.e. the magnitude of cost reduction achieved with the new technology, and the degree of differentiation of the goods produced in the industry in which the technology is applied have a significant influence on the patentholder's choice. Specifically, and irrespective of the innovation size, we reveal a threshold value for product differentiation below which the patentholder prefers to licence the innovation to all firms in the industry, rather than selling it to a single firm. However, when products are homogeneous or extremely close substitutes (hence, marketplace competition is very fierce), the choice between outright sale and licensing depends on the innovation size. Given the low degree of product differentiation, if the innovation is sufficiently minimal, sale to a single firm that subsequently licences the innovation to its competitor by means of an ad-valorem royalty outperforms the patentholder's direct licensing to both firms through contracts involving per-unit royalties; however, if the innovation is sufficiently large, licensing is preferable to sale. Overall, in almost the entire space of admissible parameters of the model, an outside patentholder prefers to directly licence the innovation rather than sell it and allow the assignee to licence to the rest of the industry. In this sense, if a joint venture between the patentholder and one of the producers is understood as technology sale, this result aligns with Anand and Khanna's (2000) finding that licensing generates larger excess returns than joint ventures. Provided that ours is a certainty context, the result is also aligned with Jeong et al.'s (2013) finding that (outside) patentholders tend to prefer to licence their patents when uncertainty is low. In contrast, our finding does not agree with some results obtained in previous literature indicating that the patentholder generally prefers to sell rather than licence an innovation (Tauman and Weng, 2012; Kabiraj and Sinha, 2014, 2016; Sinha, 2016; Banerjee and Poddar, 2019), although this conclusion (preference for outright sale over licence) arose in analytical frameworks that differ from ours.

The rationale underlying preference for licensing over outright sale is as follows. When licensing from outside the industry entails a per-unit royalty lower than the size of the innovation, granting licences to all firms in the industry enables the outside patentholder to generate the same industry rents as a multi-product monopoly; however, the patentholder cannot replicate this market outcome by selling the innovation to a single firm in the industry. Conversely, when licences from outside the industry feature a per-unit royalty that equals the size of the innovation, licensing can no longer achieve perfect collusion in the product market; therefore, the patentholder may consider selling as the optimal method to monetise the innovation rather than licensing. However, outright sale (to a single firm in the industry) only outperforms licensing when product differentiation is extremely low (i.e. competition in the marketplace is fierce) and the innovation size is minimal. In this scenario, firms end up being relatively asymmetric in production terms and the industry ends up being a quasi-monopoly. In other words, by selling the innovation to a single firm, the patentholder can better internalise industry profits through the assignee's subsequent licensing behaviour from within the industry.

Regarding the welfare consequences of innovation being transferred to the productive sector, our model shows that, relative to the scenario prior to the innovation's transfer, innovation transfer only harms consumers when made via outright sale to a given firm in the industry that further horizontally licences it. If the transfer is made by means of the patentholder's direct licensing, then consumers are either better off or, at least, not worse off than in the pre-transfer scenario even though the licence agreements include per-unit royalties. Furthermore, regardless of the monetising method, the innovation's diffusion is always welfare-enhancing. This result contradicts Mukherjee and Sinha's (2024) finding that under quantity or price competition and no royalty payments, technology licensing by an outside patentholder may be welfare decreasing when the technology is not useful for all producers; namely, if the cost reduction the technology incurs is small and the initial cost difference between producers is large. In our set-up, in which the innovation is useful for all potential users, licensing and outright sale are permissible innovation transfer schemes and royalties are feasible in licensing contracts, we determine that the innovation's transfer is welfare-enhancing. Our result also contradicts the finding by Faulí-Oller and Sandonís (2002) that licensing an inside technology to a rival firm by means of a 2PT contract (involving a per-unit royalty) is welfare-reducing. In our case, licensing within the industry may also hold (when the innovation is sold), but optimally occurs through an ad-valorem royalty, which incurs greater welfare than before licensing due to increased industry profits that offset any reduction that may hold in consumer welfare.

Regarding the welfare consequences of outright sale versus direct licensing, we show that consumers benefit from the patentholder's innovation licensing because it reduces production costs in the industry, which subsequently translates into lower final prices and higher consumer surplus. In contrast, innovation sale to an incumbent firm reduces consumer surplus because the assignee's inside licensing is made through an ad-valorem royalty, which has a collusive effect on firms in the product market. Therefore, the outside patentholder's incentives to sell the technology conflict with consumers' interests. Consequently, we determine that consumer surplus can be improved with a public policy that bans the patentholder from innovation sale (or, at least, prevents its licensing from within the industry) or that establishes an incentive for non-producing patentholders to prefer licensing to sale. Along the same lines, our analysis reveals that forming a joint venture or, alternatively, an outside patentholder takeover or merger with an incumbent firm (the potential assignee) should be scrutinised by competition authorities for potential collusive consequences in the final market.

The remainder of the paper is organised as follows. Section 2 details the background literature, and Section 3 presents the model. Sections 4 and 5 respectively describe, and solve, the sale–licensing and the licensing games. In Section 6, we determine the patentholder's optimal, whereas Section 7 covers the welfare analysis and outlines some policy directions. Finally, Section 8 concludes.

2. Literature review

An extensive body of literature has examined how and to whom an innovation is licensed by a patentholder, whether external or internal to the industry where the innovation is used to produce a product, in a full information setting. The academic attention to this issue is justified by the pivotal influence of licensing on innovation generation and dissemination and its significant market impact. Thanks to this body of research, we now better understand the optimal licensing scheme for the innovator in a wide range of economic scenarios. However, the (theoretical) literature examining the outside patentholder's choice between innovation sale or licensing is much scarcer. Table 1 summarises the literature on licensing and the choice between sale and licensing of a cost-reducing technology that is closest to our analytical framework.

The benefits of acquiring the rights of a patent and becoming an assignee rather than obtaining a licence have long been well understood in the theoretical literature. For example, Grossman and Hart (1986) noted that IP ownership mitigates the inefficiencies and potential delays in obtaining and managing a licensing contract (non-ownership arrangement) as ownership offers more residual control rights than licensing. Despite this, it was years later that Tauman and Weng (2012) introduced the idea of selling versus direct licensing of patent rights to an outside innovation. These authors demonstrated that sale is strictly better for an outside innovator in a general Cournot environment than any licensing scheme when (i) the innovation is non-drastic and significant enough and (ii) a sufficiently high number of potential (symmetric) innovation users compete in the market.[14] Our model with only two potential innovation users reveals that this outcome only persists when the innovation is extremely minimal and the goods produced are homogeneous or close substitutes. Conversely, the patentholder's optimal strategy in the scenario outlined by our model in almost the entire admissible parameter space is to licence the innovation as this transfer strategy yields a more collusive industry than outright sale.

In the context of vertically related markets, Kabiraj and Sinha (2014, 2016) showed that, regardless of whether market competition takes place through quantities or prices, a downstream firm with a technology that enables efficient input production can forgo producing the input and instead sell the technology to an upstream input supplier that produces it at a higher cost. However, our model assumes that (i) the market in which the innovation can be used is a one-tier industry rather than a

[14] In the case of a drastic innovation, both transfer strategies generate the same payoff for the patentholder.

Table 1
Relevant literature on licensing (from outside or inside patentholder) of a cost-reducing innovation and on the choice between selling and licensing.

	Authors	Main assumptions	Main findings
Licensing by an outside patentholder	Kamien and Tauman (1986)	Cournot competition in which fixed-fee payments and per-unit royalties are feasible.	Auctioning a certain number of licences allows the maximum surplus to be extracted.
	Sen and Tauman (2007), Erutku and Richelle (2007)	Two-part tariff (2PT) contracts in the form of a fixed-fee payment combined with a per-unit royalty are feasible.	The optimal contract for relatively significant innovations involves a positive royalty.
	Miao (2013)	Potential users produce a homogeneous good and are Cournot competitors. Licensing is via either a fixed-fee policy or an auction, and sublicensing is allowed.	A fixed-fee policy is better than an auction, even when sublicensing is allowed and when asymmetry between firms is minimal.
	Bagchi and Mukherjee (2014)	Cournot and Bertrand competition with differentiated products.	Irrespective of Cournot and Bertrand competition in the marketplace, royalty licensing is optimal for a certain product differentiation range.
Licensing by an inside patentholder	Mukherjee and Balasubramanian (2001)	Cournot and Bertrand duopoly market with horizontally differentiated products.	A 2PT contract with per-unit royalty is always optimal under quantity or price competition.
	Kamien and Tauman (2002)	Licensing is by fixed-fee payment or per-unit royalty contracts.	Per-unit royalty licensing is better than auctioning off a fixed number of licences outright.
	Sen and Tauman (2007)	2PT contracts with a fixed-fee payment plus per-unit royalty are practicable.	The optimal contract for relatively significant innovations incurs a positive royalty.
	San Martín and Saracho (2010, 2015)	2PT contracts with a fixed-fee payment plus per-unit or ad-valorem royalty are feasible.	Ad-valorem royalty is preferred to per-unit royalty.
	Lu and Poddar (2014)	Spatial duopoly model of competition (Salop's circular city and Hotelling's linear city).	The optimal licensing contract is a 2PT scheme with per-unit royalty, irrespective of the size of innovation or any pre-innovation cost asymmetries.
Outright sale versus licensing by	Tauman and Weng (2012)	The innovation is exploitable by symmetric-cost	If the innovation is large, outright sale is better than

(continued on next page)

Table 1 (*continued*)

	Authors	Main assumptions	Main findings
an outside patentholder		firms in an oligopoly.	licensing for an industry with more than four firms.
	Kabiraj and Sinha (2014)	A firm may source an essential input from an independent input supplier although the firm can produce it in-house at a lower cost with better technology.	For a smaller (larger) technology gap with the independent input supplier the firm would outsource (producing the input in-house for itself and for its rival).
	Sinha (2016)	The potential innovation users are cost-asymmetric Cournot duopolists that produce an homogeneous good.	Sale for a fixed-fee payment to the efficient firm who then licences the innovation to its competitor is preferable to direct licensing.
	Kabiraj and Sinha (2016)	Two Bertrand firms producing differentiated goods. One of them owns an input production technology superior to that of an independent input supplier.	If products are close substitutes or the technology gap between two input producing firms is small, strategic outsourcing occurs and technology transfer through selling functions as a commitment that the firm will outsource.
	Banerjee and Poddar (2019)	Potential innovation users are cost-asymmetric competitors in a spatial framework.	Sale to a firm that further licences the innovation to its rival is preferable to direct licensing. Social welfare is also greater.

vertically related market, (ii) the innovation belongs to an outside, not an inside, patentholder, and (iii) only belongs to an inside patentholder if purchased from the initial owner.

In a homogenous-good quantity–competition model, Sinha (2016) considered an outside innovation transfer to a duopoly with cost-asymmetric firms, determining that transfer occurs through sale only to the efficient firm. Considering that our result contradicts that finding, it is important to note the models' set-up differences. Specifically, Sinha (2016)'s model is a homogenous-good quantity–competition model that assumes asymmetric firms, whereas our model includes a differentiated good and considers symmetric firms. Therefore, while Sinha's patentholder only sells the innovation to the efficient firm, in our case, the patentholder can sell to any potential user when sale outperforms licensing. However, in contrast to Sinha (2016), we find that licensing outperforms sale in almost the entire region of admissible parameters. Moreover, in Sinha, the innovation once sold to the efficient firm is not licensed further, whereas we show that, once the innovation is sold, irrespective of its size, it will always be licensed further. Therefore, our framework reflects a high degree of technology diffusion that is absent in Sinha's framework.

Banerjee and Poddar (2019) developed a price competition model in a spatial framework from the perspective of an outside new technology patentholder, demonstrating that sale outperforms licensing, regardless of the innovation size or the degree of cost asymmetry between users. Also examining the optimal licensing contract (a mix of fixed-fee payment and royalty) arising in their spatial framework, the authors highlighted the generality and robustness of the previous research results. Our model differs from Banerjee and Poddar (2019), in that potential innovation users produce horizontally differentiated goods, are cost symmetric and compete by setting quantities. Moreover, the feasible licensing contracts in our model involve royalties that may be of the per-unit or ad-valorem type. Finally, our model also allows a variable degree of product differentiation, whereas Banerjee and Poddar's (2019) model considers firms' fixed locations in the product characteristic space, which implies a fixed degree of product differentiation.[15]

In summary, and despite the contribution from Tauman and Weng (2012) that was further expanded on by Kabiraj and Sinha (2014, 2016), Sinha (2016) and Banerjee and Poddar (2019), the theoretical literature comparing technology sale versus licensing as methods of technology transfer is limited. This study contributes to this literature by exploring the issue in a framework in which patent licensing, implemented by an outside patentholder or any potential assignee, may involve per-unit or ad-valorem royalties, combined with a fixed-fee payment or not, whereas patent sale is reduced to an agreed price. Our work contributes to the literature by extending the analysis to a context in which the outside innovation is transferred to a duopolistic industry in which firms are potentially interested in acquiring the innovation, compete à la Cournot and produce differentiated goods with old and new technology. In this setting, we add novel results by analysing the influence of innovation size and product differentiation on the commercialisation of an outside innovation and subsequent welfare impact. In addition, the achieved results will ultimately provide a framework for guiding public policy on technology transfer.

3. Model construction

Consider a duopolistic industry in which firms compete on quantities. Each firm i $(i = 1, 2)$ produces a differentiated product and faces the following residual inverse demand function:

$$p_i\left(q_i, q_j\right) = 1 - q_i - dq_j, \tag{1}$$

where q_i and q_j respectively denote the quantity produced by firms i and j $(i, j = 1, 2;\ i \neq j)$ and parameter d, $0 \leq d \leq 1$, measures the degree of product differentiation.[16]

Currently, firm 1 (F1) and firm 2 (F2) produce the goods using a technology that incurs constant returns to scale and marginal cost $c > 0$. However, a patentholder that is external to the industry has a new technology that also exhibits constant returns to scale and can reduce the marginal cost of production from c to zero. The size of the innovation is measured by cost reduction c. To ensure that the innovation is non-drastic (i.e. that each firm i remains active in the market regardless of the degree of product differentiation, and even if competitor j but not firm i receives the new technology), the following assumption is made:

Assumption A1. For a degree of product differentiation d $(0 \leq d \leq 1)$, the innovation size, c, is such that $0 \leq c < \overline{c}(d)$, with $\overline{c}(d) \equiv 1 - \frac{d}{2}$.

[15] Caviggioli et al. (2020) presented statistics on the monetization strategies concerning patents owned by the top 58 US universities in the 2002–2010 period. These authors found that 37 % of the patents granted by the United States Patent and Trademark Office involved a form of monetization wherein 29.7 % were licensed out; 5.9 % were reassigned to other universities, national laboratories, federal agencies or non-profit entities; and 1.3 % were transferred to companies.

[16] The demand in Eq. (1) comes from the utility function $u(q_1, q_2) = q_1 + q_2 - dq_1q_2 - (q_1^2 + q_2^2)/2$.

The patentholder lacks capacity to convert the innovation into practical application and useful product; therefore, it must monetise the innovation by selling or licensing it to some firm(s) in the industry. The game according to which the innovation is transferred to the industry has four stages as follows.

- In the first stage, the patentholder decides whether to sell or licence the innovation.
- If the patentholder sells the innovation to a single firm, the ownership rights pass to this firm (the assignee) for an agreed price. In the second stage, the assignee decides whether to use the innovation exclusively or to licence it to its competitor in the product market (also deciding the corresponding contractual terms). In the third stage, the (potential) licensee accepts or rejects the assignee's offer. Finally, in the fourth stage, the producing firms compete as Cournot players in the marketplace by setting quantities. If the innovation is simultaneously sold to both firms in the first stage, the game continues with each firms' acceptance or rejection and marketplace competition.
- Alternatively, if the patentholder licences the innovation in the first stage of the game rather than selling, then it only transfers technology use rights to the licensee(s) so they can manufacture and sell their products using the transferred technology. In the second stage, the patentholder decides how and to whom to licence the innovation. In the third stage, each potential licensee accepts or rejects the patentholder's offer. Finally, in the fourth stage, irrespective of whether they have access to new technology or not, the producing firms play as Cournot competitors in the product market.

We assume that the innovation owner—either the original patentholder or the assignee—has all the bargaining power when setting the contractual terms for transfer by means of outright sale or licensing, leaving the assignee or the licensee(s) with only their respective outside options. We also assume no costs for either innovation sale or licensing. We look for the subgame Nash perfect equilibrium as the solution concept for sale–licensing and pure licensing games.

4. Patentholder sells the innovation

Once the patentholder has sold the innovation to one of the producing firms (e.g. F1) in exchange for an agreed price, F1, as the new owner, can play as an 'inside patentholder' and is free to decide whether to use the innovation on an exclusive basis or offer a licence to F2, its direct competitor in the marketplace. We allow for a licensing deal consisting of a 2PT contract in the form of a fixed-fee payment combined with a per-unit or ad-valorem royalty, i.e. a royalty based on units produced by F2 or a royalty based on percentage of F2's profits, respectively.[17] Throughout the article, superscript n denotes a scenario in which the assignee (if it is just one) does not licence to the competitor in the marketplace; superscripts l and s respectively denote licensing and sale as mechanisms for innovation transfer; superscripts U and V indicate respective licensing regimes based on a fixed-fee payment combined with per-unit royalty and combined with ad-valorem royalty; and finally, subscript PH refers the patentholder.

4.1. Assignee licences the innovation through a 2PT contract featuring per-unit royalty

In this section, we assume that the patentholder sells the innovation to a single firm (e.g. F1). Once F1 has purchased the innovation, it becomes the assignee and must choose whether to licence the innovation to its competitor F2 (the licensee) or use it on an exclusive basis. If F1 licences the innovation by means of a 2PT contract shaped as (f, r), with $f \geq 0$ and $0 \leq r \leq c$,[18] then in the fourth stage of the game, F2 chooses to produce the quantity that solves:

$$\max_{q_2} \{(1 - dq_1 - q_2 - r)q_2 - f\}, \text{s.t} : q_2 > 0, \tag{2}$$

while F1 (the assignee), acting as licensor, produces the quantity that solves:

$$\max_{q_1} \{(1 - q_1 - dq_2)q_1 + rq_2 + f\}, \text{s.t} : q_1 > 0. \tag{3}$$

Solving Eqs. (2) and (3), we obtain $q_1^R = \frac{2-d+dr}{4-d^2}$ and $q_2^R = \frac{2-d-2r}{4-d^2}$ as the respective equilibrium outputs produced by F1 and F2. As a result, internal profits amount to $\pi_1^R = \frac{(2-d+dr)^2}{(4-d^2)^2}$ for F1 and $\pi_2^R = \frac{(2-d-2r)^2}{(4-d^2)^2}$ for F2. In the third stage of the game, F2 will accept the offered licence if it leads to $\pi_2^R - f \geq \pi_2^n$, where π_2^n is F2's profit in the outside option (i.e. when it produces at marginal cost $c > 0$ whereas F1 produces at zero marginal cost) and equals profit π_2^R evaluated at $r = c$, i.e. $\pi_2^n = \frac{(2-d-2c)^2}{(4-d^2)^2}$. Therefore, in the second stage of the game, F1's optimal licensing contract is that which maximises its payoff subject to the restrictions imposed in the third and fourth stages. Formally, F1 sets the contractual terms that solve the following:

$$\max_{(f,r)} \{\pi_1^R + f + rq_2^R\}, \text{s.t} : q_1 > 0, q_2 > 0, r \leq c \text{ and } f \leq \pi_2^R - \pi_2^n, \tag{4}$$

yielding $r^* = \min\left\{\frac{d(2-d)^2}{2(4-3d^2)}, c\right\}$ as the optimal per-unit royalty and, consequently, $f^* = \pi_2^R - \pi_2^n$ is the fixed part of the tariff. This enables us to establish the following result:

Lemma 1. *A cut-off value for the size of innovation exists, $c_1(d) \equiv \frac{d(2-d)^2}{2(4-3d^2)}$, such that if both fixed-fee payments and per-unit royalties are contractually feasible, the assignee licences the innovation to its market competitor as follows:*

(i) *If the innovation is sufficiently small, at $c \leq c_1(d)$, by means of a pure per-unit royalty contract, $r^* = c$.*
(ii) *If the innovation is sufficiently large, at $c > c_1(d)$, by means of a 2PT contract,*
$$(f^*, r^*) = \left(\frac{d(2-d)^3(-8+2d+5d^2)+4(2-d)(4-3d^2)^2c-4(4-3d^2)^2c^2}{(4-d^2)^2(4-3d^2)^2}, \frac{d(2-d)^2}{2(4-3d^2)}\right),$$ *with $f^* > 0$ and $r^* < c$.*

When fixed-fee payments and per-unit royalties are contractually feasible, the assignee (F1) receives royalties from F2 while controlling F2's production cost, mitigating fierce competition in the product market. This ensures that F1 always finds it profitable to licence the innovation, regardless of its size, with a contract that always features a strictly positive per-unit royalty.

The royalty rate enables F1 to obtain revenue and control the market, diminishing competition because F2, with increased production costs above those resulting from the new technology, is compelled to either reduce output or raise prices. Because a per-unit royalty enables F1 to control its own and F2's market behaviour in production terms, F1

[17] As 2PT contracts involving fixed payments combined with per-unit or ad-valorem royalties are considered in the analysis, we omit licensing by means of a pure fixed-fee payment because it represents a special case of the analysis in which the optimal per-unit or ad-valorem royalty is zero.

[18] We do not allow for negative fees, as licensing arrangements could enable the patentholder to 'bribe firms to exit the industry and would likely be held illegal by antitrust authorities' (Katz and Shapiro, 1985). Therefore, if the patentholder licenses the innovation as an outside licensor, the non-negativity of the fixed fee implies that the royalty cannot exceed the innovation size. Furthermore, it is common to assume that when the patentholder is an insider, the royalty cannot exceed the innovation size because—as argued by Banerjee et al. (2022)—the licensee would prefer to use the old technology to avoid paying any royalty.

determines the per-unit royalty that maximises industry profits. This generates an additional fixed-fee payment when maximising industry profits requires setting $r^* < c$ to enable extraction of additional rents that F2 obtains in the product market.

Whether or not the licence incorporates a positive fixed-fee payment depends on the degree of differentiation of the goods produced by the firms and the innovation size. Given the differentiation degree, if the innovation is relatively minimal, it is licenced by means of pure per-unit royalty equal to the size of the innovation, $r^* = c$, which leads F2 to produce at the same cost as before licensing and earn the same profit. Therefore, any competitive pressure from F2 due to licensing disappears and the fixed fee vanishes. In summary, sale of a small innovation would only improve the assignee's productive efficiency, not overall industry efficiency.

However, given the degree of product differentiation, when the innovation size is sufficiently large, the licence is a 2PT contract featuring a per-unit royalty less than the size of the innovation, $r^* < c$, and a positive fixed-fee payment, $f^* > 0$. In this case, F2 produces at a lower cost than before licensing and all firms are more efficient than before the innovation was transferred. At the same time, by imposing a strictly positive per-unit royalty, the assignee (F1) can reduce competitive pressure from F2, while the (positive) fixed fee allows it to benefit from F2's increased profits.

Fig. 1 graphically illustrates the result of Lemma 1 in the (d, c) region of admissible parameters.

Finally, as result of its own profit and licensing income, F1's overall payoff, $B_1^R = (1 - q_1^R - dq_2^R)q_1^R + f^* + r^* q_2^R$, amounts to the following:

$$B_1^R = \begin{cases} \dfrac{(2-d)^2 + (8 - 4d^2 + d^3)c - (8 - 3d^2)c^2}{(4-d^2)^2}, \text{if } c \le c_1(d) \\ \dfrac{(2-d)^2(16 - 8d^2 - 4d^3 + d^4) + 16(8 - 4d - 6d^2 + 3d^3)c - 16(4 - 3d^2)c^2}{4(4-3d^2)(4-d^2)^2}, \text{if } c > c_1(d) \end{cases} \quad (5)$$

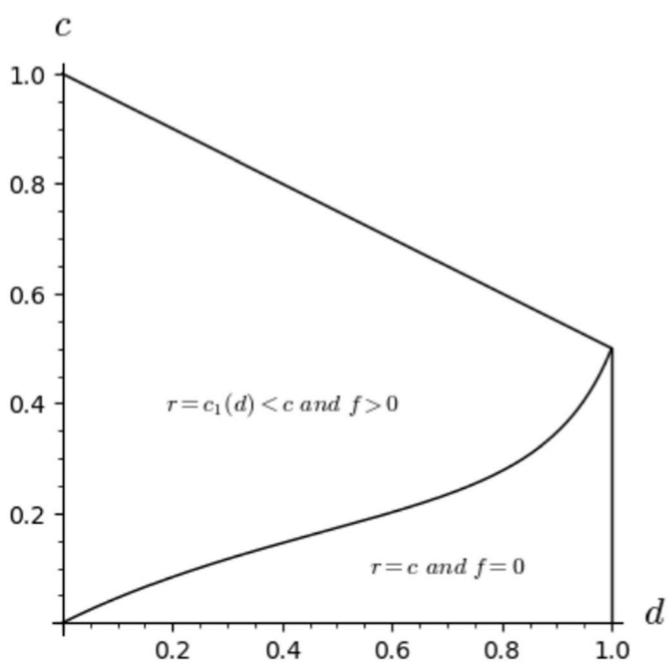

Fig. 1. Optimal licensing for the assignee when fixed-fee payments and per-unit royalties are contractually feasible.

4.2. Assignee licences the innovation by means of a 2PT contract with ad-valorem royalty

In this case, F1 grants a licence to F2 including a fixed payment f, where $f \ge 0$, combined with an ad-valorem royalty v, $0 \le v \le 1$, which is calculated as a share of F2's profits. Therefore, in the fourth stage of the game, F2 chooses to produce the quantity that solves:

$$\max_{q_2} \{(1-v)(1 - dq_1 - q_2)q_2 - f\}, \text{s.t} : q_2 > 0, \quad (6)$$

whereas F1 chooses to produce the quantity that solves:

$$\max_{q_1} \{(1 - q_1 - dq_2)q_1 + v(1 - dq_1 - q_2)q_2 + f\}, \text{s.t} : q_1 > 0. \quad (7)$$

Solving Eqs. (6) and (7) yields $q_1^V = \frac{2-(1+v)d}{4-(1+v)d^2}$ and $q_2^V = \frac{2-d}{4-(1+v)d^2}$ as the respective equilibrium outputs for F1 and F2. Therefore, $p_1^V = \frac{2-d+d(1-d)v}{4-(1+v)d^2}$ and $p_2^V = \frac{2-d}{4-(1+v)d^2}$ are the equilibrium market prices for the goods produced by F1 and F2, respectively, while $\pi_1^V = \frac{(2-d-dv)[2-d+d(1-d)v]}{[4-(1+v)d^2]^2}$ and $\pi_2^V = (1-v)p_2^V q_2^V = (1-v)\frac{(2-d)^2}{[4-(1+v)d^2]^2}$ are their respective profits from product sales. Given that $\frac{\partial q_1^V}{\partial v} < 0$ and $\frac{\partial q_2^V}{\partial v} > 0$, the ad-valorem royalty leads F1 to reduce its output level compared to when the ad-valorem royalty is zero because the royalty enables F1 to internalise F2's increased profits. In other words, the ad-valorem royalty leads to a redistribution of industry production wherein F1's production decreases while F2's production increases. Therefore, F1 faces a trade-off when determining the optimal value of the ad-valorem royalty in which an increase in v reduces its profit from product sales (π_1^V) and the revenue from the fixed part of the licensing contract (f) but increases the licensing income received through the variable factor of the contract, $vp_2^V q_2^V$.

In the third stage of the game, F2 only accepts the licence offered if its profit from the innovation, $\pi_2^V - f = (1-v)p_2^V q_2^V - f$, is at least π_2^n, the alternative profit earned if F2 rejects the licence, and consequently continues to produce with the old technology.

Finally, in the second stage of the game, F1 sets the licensing contract that maximises its total payoff subject to the restrictions imposed by the second and third stages of the game. Formally, F1 solves the following:

$$\max_{(f,v)} \{\pi_1^V + f + vp_2^V q_2^V\}, \text{s.t} : q_1^V > 0, q_2^V > 0, 0 \le v \le 1 \text{ and } 0 \le f \le \pi_2^V - \pi_2^n, \quad (8)$$

and the ad-valorem royalty that maximises industry profits,

$$v^* = 1 - \frac{2d(1-d)}{4 - 2d - d^2}, \quad (9)$$

reaches its maximum value, $v^* = 1$, when $d = 0$ (i.e. when firms are two independent monopolies with demands completely decoupled and market competition is minimal) or when $d = 1$ (i.e. both firms produce a homogeneous good and competition is maximal), whereas it reaches its minimum value, $v^* = 4/5$, when $d = 2/3$ (i.e. when both firms produce products that are moderate substitutes). In any case, the optimal ad-valorem royalty v^* $(0 < v^* \le 1)$ in Eq. (9) can be implemented when the resulting fixed part of the contract, $f = \pi_2^V - \pi_2^n$, is strictly positive. Otherwise, given our assumption of a non-negative fixed-fee payment, the optimal ad-valorem royalty is that which saturates the licensee's participation constraint as follows:

$$\pi_2^V - \pi_2^n = (1-v)\frac{(2-d)^2}{\left[4-(1+v)d^2\right]^2} - \frac{(2-d-2c)^2}{\left(4-d^2\right)^2} = 0. \tag{10}$$

From Eqs. (9) and (10) we arrive at the following lemma.

Lemma 2. *A cut-off value for the size of the innovation exists,* $c_2(d) \equiv \frac{(2-d)[2(4-3d^2)-(2+d)\sqrt{2d(1-d)(4-2d-d^2)}]}{2(4-3d^2)}$*, such that if fixed-fee payments and ad-valorem royalties are contractually feasible, the assignee licences the innovation to its market competitor as follows:*

(i) *If the innovation size is* $c \le c_2(d)$*, by means of pure ad-valorem royalty* $v^* = \frac{(4-d^2)A}{2d^4(2-d-2c)^2}$*, where* $A = (2-d)$

$$\sqrt{\begin{matrix}64-64d-80d^2+96d^3+12d^4-36d^5+9d^6+32c\\ (2-d-c)\left(2-d^2\right)d^2\end{matrix}}$$

$$-16+16d+8(1-c)^2d^2-4(3-2c)d^3+3d^4.$$

(ii) *If the innovation size is* $c > c_2(d)$*, by means of 2PT contract* $(f^*, v^*) = \left(\frac{-(2-d)^3(16-20d^2-2d^3+7d^4+d^5)+8(2-d)(4-3d^2)^2c-8(4-3d^2)^2c^2}{2(4-d^2)^2(4-3d^2)^2}, 1-\frac{2d(1-d)}{4-2d-d^2}\right)$.

When fixed-fee payments and ad-valorem royalties are contractually feasible, the optimal licence for the assignee (F1) always involves a strictly positive royalty rate that leads it to behave less aggressively in the product market and leads the licensee (F2) to behave more aggressively than if the ad-valorem royalty were zero. Part (i) of Lemma 2 establishes that the licence does not include a fixed fee when, given the degree of product differentiation, the innovation is sufficiently minimal. In this case, to increase the market price and F2's production as much as possible, the ad-valorem royalty is set at the highest admissible value, which is the value that saturates F2's participation constraint.

However, if the innovation is sufficiently large, as shown in part (ii) of Lemma 2, then in addition to an ad-valorem royalty, the licence includes a strictly positive fixed-fee, $f^* > 0$. This is because F2's profit in the outside option, $\pi_2^n = \frac{(2-d-2c)^2}{(4-d^2)^2}$, would be extremely low due to the high-cost disadvantage compared to F1. Therefore, the ad-valorem royalty that maximises industry profits in Eq. (9) is feasible because F2's profit evaluated at this ad-valorem royalty, π_2^V, is such that $\pi_2^V - \pi_2^n > 0$; consequently, F1 can charge a fixed fee equal to F2's increased profits.

Fig. 2 illustrates the result of Lemma 2 in the (d, c) region of admissible parameters, where $v(d,c)$ denotes the optimal ad-valorem royalty stated in part (i) of Lemma 2, and $v(d)$ denotes the optimal ad-valorem royalty indicated in part (ii) of Lemma 2.

From Lemma 2, the assignee's overall payoff, i.e. its own profit plus licensing revenue, $B_1^V = \pi_1^V + f^* + v^* p_2^V q_2^V = \frac{[2-d(1+v^*)][2-d+d(1-d)v^*]}{[4-d^2(1+v^*)]^2} + \frac{(2-d)^2}{[4-d^2(1+v^*)]^2} - \frac{(2-d-2c)^2}{(4-d^2)^2}$, amounts to the following:

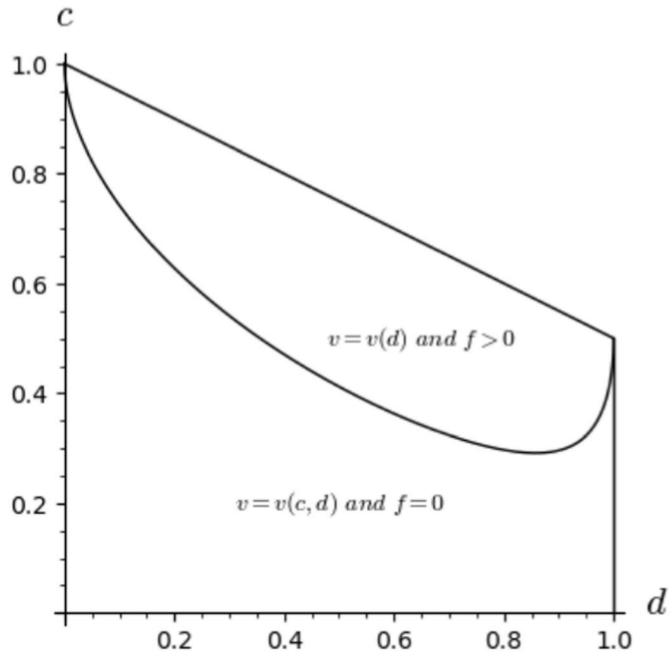

Fig. 2. Optimal licensing for the assignee when fixed-fee payments and ad-valorem royalties are contractually feasible.

Finally, from Eqs. (5) and (11), the following result holds.

Proposition 1. *Let* $c_3(d) \equiv \frac{3}{2} - \frac{1}{d}$*. When fixed fees and (per-unit and ad-valorem) royalty payments are contractually practicable, the assignee licences the innovation to its market competitor as follows:*

(i) *If* $0 < d < 2(\sqrt{2}-1)$ *and* $c_1(d) < c < c_2(d)$*, through a 2PT contract involving a per-unit royalty as stated in Lemma 1 (ii).*

(ii) *If* $0 < d < 2(\sqrt{2}-1)$ *and* $\max\{0, c_3(d)\}\langle c < c_1(d)$*, through a pure per-unit royalty as stated in Lemma 1 (i).*

(iii) *If* $\frac{2}{3} < d < 1$ *and* $0 < c < \min\{c_2(d), c_3(d)\}$ *through a pure ad-valorem royalty as stated in Lemma 2 (i).*

(iv) *If* $2(\sqrt{2}-1) < d \le 1$ *and* $c_2(d) < c < c_1(d)$*, through a 2PT contract involving an ad-valorem royalty as stated in Lemma 2 (ii).*

(v) *If* $0 < d < 1$ *and* $\max\{c_1(d), c_2(d)\}\langle c < \overline{c}(d)$*, the assignee is indifferent between using a 2PT contract involving a per-unit royalty as stated in Lemma 1 (ii) or a 2PT contract involving an ad-valorem royalty as stated in Lemma 2 (ii).*

As an 'insider licensor', the assignee is not only concerned about licensing revenue, but also about the impact of licensing on its market position. Therefore, it always charges some type of royalty, either per-unit or ad-valorem, in the licence offered to its competitor. When the goods are homogeneous, the inside licence involves and ad-valorem royalty coupled or not with a fixed payment, depending of the innovation size. In this case, market rivalry is extremely fierce and the ad-

$$B_1^V = \begin{cases} \dfrac{\begin{matrix}-32(8-A)+16(16-A)d+32(16-A)d^2-8(64-A)d^3-\left[320-14A-16(2-d)\left(2-d^2\right)c+16\left(2-d^2\right)c^2\right]d^4\\ +(336-A)d^5+2(36-A)d^6-88d^7-(1-6d)d^8\end{matrix}}{8d^2\left(8-6d^2+d^4\right)^2}, & \text{if } c \le c_2(d)\\[2ex] \dfrac{(2-d)^2\left(16-8d^2-4d^3+d^4\right)+16\left(8-4d-6d^2+3d^3\right)c-16\left(4-3d^2\right)c^2}{4\left(4-3d^2\right)\left(4-d^2\right)^2}, & \text{if } c > c_2(d)\end{cases} \tag{11}$$

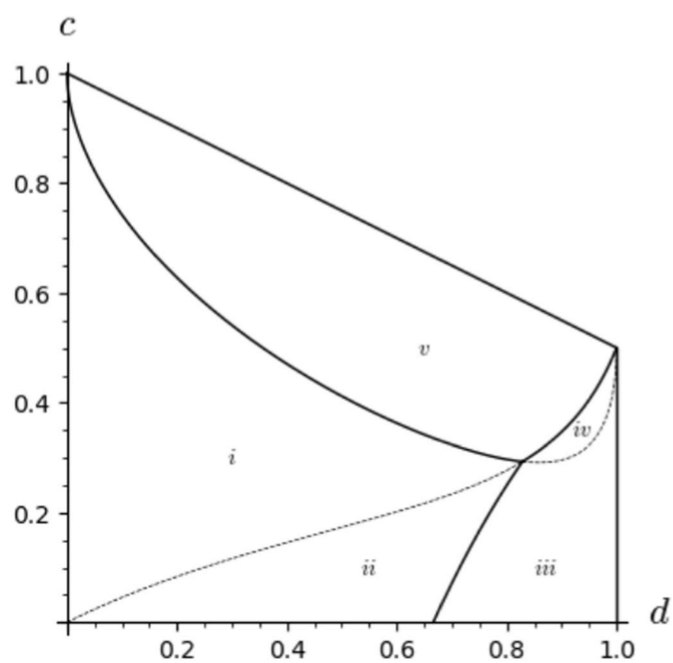

Fig. 3. Optimal licensing for the assignee when fixed-fee payments and royalties, either per-unit or ad-valorem, are contractually feasible.

valorem royalty, which is unequivocally a more effective collusion device than a per-unit royalty, enables the assignee to capture the resulting increase in profits.[19]

If the goods are close substitutes rather than homogeneous, the superiority of the ad-valorem royalty over the per-unit royalty persists. In particular, given the degree of product differentiation, when the innovation's size is minimal or moderate, ad-valorem royalties outperform per-unit royalties because with a per-unit royalty, the assignee's capacity to restrict marketplace competition is limited. However, when, given the degree of product differentiation, the innovation is sufficiently large, then the assignee is indifferent to including a per-unit or ad-valorem royalty in the 2PT contract as both yield equivalent industry profits. In other words, the assignee can use ad-valorem and per-unit royalties interchangeably.

Finally, if the assignee and licensee produce distant substitutes and, consequently, market competition between them is weak, the assignee prefers the per-unit to the ad-valorem royalty when, given the degree of product differentiation, the size of innovation is small or moderate, with the per-unit royalty at the ceiling, $r^* = c$, or below that ceiling, $r^* < c$, respectively. Conversely, given the degree of product differentiation, if the innovation is sufficiently large, then both types of royalties are again equally profitable for the assignee.

Fig. 3 illustrates the result of Proposition 1 in the (d, c) region of admissible parameters, where the notation *i*–*v* refers to the contractual terms of the licence established in parts (i)–(v) of Proposition 1.

5. Patentholder licences the innovation

In this section, we consider the decision of the patentholder who retains ownership of its innovation regarding whether to offer one or two licences and the contractual terms in each case. Irrespective of whether one or two licences are issued, the contractual terms are assumed to be a fixed-fee payment combined with either per-unit or ad-valorem royalty.

[19] The ad-valorem royalty enables the assignee to strengthen industry collusion, while the per-unit royalty has limited effects because it only reaches its ceiling, $r = c$, when d is below 0.8482 and the innovation is sufficiently small.

5.1. Patentholder issues a single licence

Suppose that the patentholder licences the new technology to a single firm (e.g. F1) by means of a 2PT contract shaped as (f_1, r_1), with $f_1 \geq 0$ and $0 \leq r_1 \leq c$. Since each firm's outside option is the possibility that the rival can use the new technology on an exclusive basis, the fixed-fee payment in the contract equals the increase in profits from being the licensee. If F1 is the licensee, then in the fourth stage of the game, it produces the output level that solves the following:

$$\max_{q_1} \{(1 - r_1 - q_1 - dq_2)q_1 - f_1\}, \text{s.t} : q_1 > 0, \tag{12}$$

whereas F2 (the non-licensee) chooses to produce the quantity that solves:

$$\max_{q_2} (1 - c - dq_1 - q_2)q_2, \text{s.t} : q_2 > 0. \tag{13}$$

The resulting equilibrium outputs for F1 and F2 are $q_1^R(r_1, c) = \frac{2-d+dc-2r_1}{4-d^2}$ and $q_2^R(r_1, c) = \frac{2-d-2c+dr_1}{4-d^2}$, respectively, and then the patentholder can set a fixed-fee payment (f_1) equal to the difference in firms' profits as follows:

$$f_1 = \left(q_1^R\right)^2 - \left(q_2^R\right)^2. \tag{14}$$

From here, in the second stage of the game, the optimal licensing contract set by the patentholder involves the per-unit royalty that solves the following:

$$\max_{r_1} \{f_1 + r_1 q_1^R\}, \text{s.t} : f_1 \leq \left(q_1^R\right)^2 - \left(q_2^R\right)^2 \text{ and } 0 \leq r_1 \leq c_1, \tag{15}$$

which yields $r_1^* = 0$ as the optimal royalty rate. That is, the patentholder, as an external licensor wanting to avoid reducing the productive efficiency of the licensee, does not want to charge any royalty which would reduce licensing income from royalties and the fixed part of the contract. In summary, even if a per-unit royalty is contractually feasible, the patentholder prefers to licence by means of a contract that degenerates into the fixed-fee payment obtained from Eq. (14) when the per-unit royalty is zero, i.e. the fixed-fee contract $f_1^* = \frac{(2-d+dc)^2}{(4-d^2)^2} - \frac{(2-d-2c)^2}{(4-d^2)^2} = \frac{(2-c)c}{4-d^2}$.

In contrast, if the patentholder grants a licence to F1 through a 2PT contract shaped as (f_1, v_1), where $f_1 \geq 0$ and $0 \leq v_1 \leq 1$, then after licensing, F1 produces the quantity that solves the following:

$$\max_{q_1} \{(1 - v_1)(1 - q_1 - dq_2)q_1 - f_1\}, \text{s.t} : q_1 > 0, \tag{16}$$

whereas F2 produces the quantity that solves the same problem as in Eq. (13). The corresponding equilibrium output levels for F1 and F2 are $q_1^V = \frac{2-d+dc}{4-d^2}$ and $q_2^V = \frac{2-d-2c}{4-d^2}$, respectively. From here, the patentholder can charge the following fixed-fee payment:

$$f_1 = (1 - v)\left(q_1^V\right)^2 - \left(q_2^V\right)^2; \tag{17}$$

thus, in the second stage of the game, its payoff amounts to the following:

$$f_1 + v_1\left(q_1^V\right)^2 = \left(q_1^V\right)^2 - \left(q_2^V\right)^2 = \frac{(2-c)c}{4-d^2}. \tag{18}$$

Since the ad-valorem royalty cannot modify the quantities that firms choose to produce compared to those produced when there is no ad-valorem or per-unit royalty, i.e. $q_1^V = q_1^R(0, c) = \frac{2-d+dc}{4-d^2}$ and $q_2^V = q_2^R(0, c) = \frac{2-d-2c}{4-d^2}$, the patentholder can achieve the same profits when the licence adopts the form of any contract (f_1^*, v_1^*) that satisfies $v_1^* \in \left[0, 1 - \left(\frac{q_2^V}{q_1^V}\right)^2\right]$ and $f_1^* = (1 - v_1^*)(q_1^V)^2 - (q_2^V)^2$. Any choice allows the patentholder to obtain the payoff given by $(q_1^V)^2 - (q_2^V)^2$. Furthermore, in any of these contracts, it follows that the fixed part f_1^* increases and the royalty rate v_1^* decreases when, given the innovation size, the degree of product differentiation increases. This is because the output level of F1 (the licensee) increases as product differentiation increases, while the price charged for its product and its revenue both decrease. Therefore, the patentholder finds it optimal to reduce the ad-valorem royalty charged to F1.

Finally, since the licensing revenue collected under any of these contracts coincides with that which is obtained from a fixed-fee contract, the following result emerges.

Lemma 3. *If both fixed-fee payments and per-unit or ad-valorem royalties are contractually feasible, then a single licence for the innovation is granted through any contract* (f^*, v^*) *satisfying* $v^* \in \left[0, 1-\left(\frac{q_2^V}{q_1^V}\right)^2\right]$ *and* $f^* = (1-v^*)(q_1^V)^2 - (q_2^V)^2 = \frac{(2-c)c}{4-d^2} - v^*(q_1^V)^2$.

That is, under full information, an outside, non-producing patentholder licences a cost-reducing innovation to a single firm in the industry either through a fixed-fee payment, a pure ad-valorem royalty or a combination of both in a 2PT contract. In any case, the licensing scheme avoids distorting the licensee's production and allows the patentholder to extract the licensee's increased innovation-attributable profits.

5.2. Patentholder issues two licences

To examine the game scenario when the patentholder grants a licence to firms F1 and F2, we make use of the following assumption.

Assumption A2. If firm i accepts the licence offered to it, but its rival j rejects the licence offered to it, the patentholder may rescind the offers and offer firm i a new contract that maximises the joint profits.

If the patentholder grants two licences, each by means of a 2PT contract shaped as (f_i, r_i), $i = 1, 2$, and both firms accept, then in the fourth stage of the game, each licensee i produces the output level $q_i^R = \frac{2-d-2r_i+dr_j}{4-d^2}$ $(i, j = 1, 2; i \neq j)$. According to Assumption A2, when firm i accepts the offered licence, but rival j does not accept, the contract offered to firm i is modified into another contract, which maximises joint profits with firm i as the only targeted firm. This results in a new deal as stated in Lemma 3, and in the second stage the patentholder sets the per-unit royalties that solve the following:

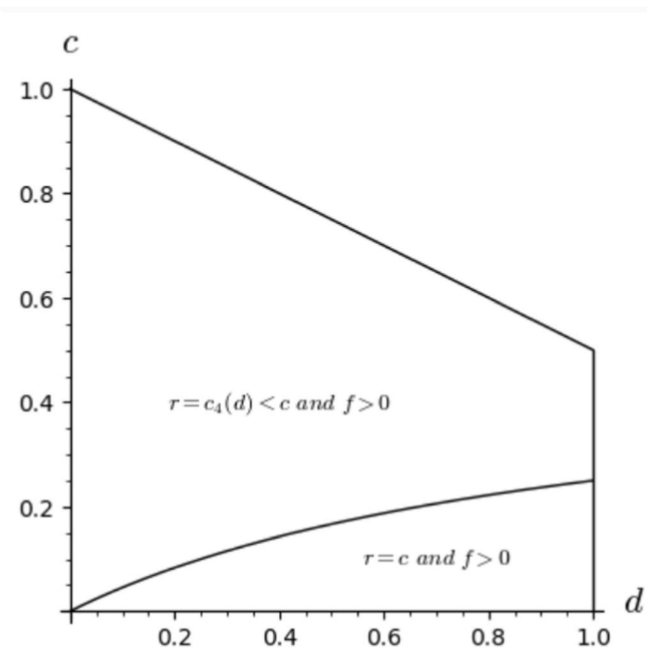

Fig. 4. Form of each licence when the patentholder licences the innovation to both firms.

(i) *If the size of the innovation is small, at* $c \leq c_4(d)$*, then* $(f_i^*, r_i^*) = \left(\frac{2d(2-d)-d(4-d)c)c}{(4-d^2)^2}, c\right)$.

(ii) *If the size of the innovation is large, at* $c > c_4(d)$*, then* $(f_i^*, r_i^*) = \left(\frac{1}{4(1+d)^2} - \frac{(2-d-2c)^2}{(4-d^2)^2}, c_4(d)\right)$*, that is* $r_i^* < c$.

That is, each licence consists of a 2-PT contract involving a per-unit royalty that, when the innovation is sufficiently small, achieves its ceiling, $r_i^* = c$, leading the firms' production costs not to be reduced. In this case, industry efficiency does not improve with respect to the old technology's efficiency. However, if the cost reduction driven by the innovation is sufficiently large, then $r_i^* < c$, i.e. the royalty charged to each firm is less than the cost reduction resulting from being a licensee, in which case technology diffusion improves industry efficiency.

$$\max_{(r_1, r_2)} \left\{ \begin{array}{c} \frac{(2-d-2r_1+dr_2)^2}{(4-d^2)^2} - \frac{(2-d-2c)^2}{(4-d^2)^2} + \frac{(2-d-2r_2+dr_1)^2}{(4-d^2)^2} - \frac{(2-d-2c)^2}{(4-d^2)^2} + r_1\frac{2-d-2r_1+dr_2}{4-d^2} + r_2\frac{2-d+dr_1-2r_2}{4-d^2} \\ \text{s.t} : 0 \leq r_i \leq c \ (i = 1, 2) \end{array} \right\}, \tag{19}$$

which yields $r_i^* = \min\{\frac{d}{2(1+d)}, c\}$, $i = 1, 2$, as the optimal per-unit royalty included in each contract.[20] From here, the following result ensues:

Lemma 4. *Let* $c_4(d) \equiv \frac{d}{2(1+d)}$*. When both fixed-fee payments and per-unit royalties are contractually feasible, two licences for the innovation are granted through 2PT contracts* (f_i^*, r_i^*)*,* $i = 1, 2$*, as follows:*

From Lemma 4, the quantity produced by each licensee i is as follows:

$$q_i = \begin{cases} \frac{1-c}{2+d}, \text{if } c \leq c_4(d) \\ \frac{1}{2(1+d)}, \text{if } c > c_4(d) \end{cases}, \tag{20}$$

and the patentholder's payoff amounts to the following:

$$\pi_{PH}^{I,R} = \begin{cases} \frac{\left[2(8-4d^2+d^3)-2(8-3d^2+d^3)c\right]c}{(4-d^2)^2}, \text{if } c \leq c_4(d) \\ \frac{d^2(2-d)^2+16(2+d-d^2)c-16(1+d)c^2}{2(1+d)(4-d^2)^2}, \text{if } c > c_4(d) \end{cases}. \tag{21}$$

[20] Note that for all $0 \leq d \leq 1$, it is verified that $\frac{d}{2(1+d)} < 1 - \frac{d}{2}$, where, according to Assumption 1, $1 - \frac{d}{2}$ is the maximum value considered for parameter c.

Finally, if the patentholder grants two licences by means of 2PT contracts shaped as (f_i, v_i), $i = 1,2$, then, given the F1 and F2 equilibrium outputs in the fourth stage and the F1 and F2 licence acceptance in the third stage, in the second stage of the game the patentholder sets the contracts that solve the following problem:

$$\max_{(f_i,v_i)} 2\left(f_i + v_i \frac{1}{(2+d)^2}\right), \text{s.t}: f_i \leq \frac{1-v_i}{(2+d)^2} - \frac{(2-d-2c)^2}{(4-d^2)^2} \text{ and } 0 \leq v_i \leq 1, \quad (22)$$

whose solution is any (f_i^*, v_i^*) arrangement such that $f_i^* + v_i^* \frac{1}{(2+d)^2} = \frac{4(2-d-c)c}{(4-d^2)^2}$, $i = 1, 2$. Therefore, the patentholder's payoff when any of these contracts is offered to each firm amounts to the following:

$$\pi_{PH}^{l,V} = \frac{8(2-d-c)c}{(4-d^2)^2}, \quad (23)$$

which is the same as that obtained from granting two licences through fixed-fee contracts.

From here, comparison of payoffs in Eqs. (18), (21) and (23) enables us to establish the following result.

Proposition 2. *When the patentholder directly licences the innovation, it grants two licences through 2PT contracts involving the per-unit royalties stated in Lemma 4, and its revenue is as given in Eq. (21).*

When an outside patentholder directly licences a cost-reducing innovation to a duopolistic industry, it does so to both potential users by means of 2PT contracts including per-unit royalties. This is because the patentholder cannot reduce industry competition (and thus increase the payment that each final good producer is willing to pay for its respective licence) through the concession of a single licence or using ad-valorem royalties. Therefore, the patentholder opts to licence both firms in the industry and resort to per-unit royalties.

Fig. 4 illustrates the result stated in Proposition 2 in the (d, c) region of admissible parameters.

When, given the degree of product differentiation, the size of the innovation is sufficiently large and the licence to both firms in the industry implies the use of the per-unit royalties indicated in the upper region of Fig. 4, then the patentholder can obtain the rents from a multi-product monopoly (less firms' profits in the outside option) as the patentholder ensures maximum collusion in the industry. This collusion is not achievable with patent sale to a single firm (that subsequently licences the innovation to its competitor by means of an ad-valorem royalty); therefore, licensing in that upper region of Fig. 4 is unequivocally superior to outright sale. However, in the lower region of Fig. 4, the innovation is sufficiently minimal and, given the degree of product differentiation, the per-unit royalty the patentholder charges for licensing the innovation to both firms is less than the innovation size, which prevents the patentholder from generating maximum collusion in the industry. Therefore, innovation sale may be the right strategy for the patentholder, particularly when the products are weakly differentiated and the innovation serves to reduce the licensees' production costs by very little, in which case the per-unit royalty featuring in each licensing contract would be extremely small.

6. Patentholder's decision

In this section, we solve the first stage of the game induced by the innovation's sale and the first stage of the game induced by innovation licensing. How much can the patentholder charge for the innovation sold to a single firm (e.g. F1)? If the patentholder sells the innovation to F2 rather than F1 and F2 licences it to F1, then F1 obtains the profit $\pi_1^n = \frac{(2-d-2c)^2}{(4-d^2)^2}$. Since this is F1's profit in the outside option (i.e. if the innovation is sold to F2 and F2 would licence it to F1), the price to be paid by F1 amounts to $S = \max\{B_1^R, B_1^V\} - \pi_1^n$, where B_1^R is defined in Eq. (5) and B_1^V is defined in Eq. (11). Alternatively, if the patentholder directly licences the innovation (to both firms), its payoff amounts to $\pi_{PH}^{l,R}$, as shown in Eq. (21). Therefore, and since the assignee licences its rival by means of ad-valorem royalty, the patentholder's optimal decision in the first stage of the game can be summarised in the following proposition:

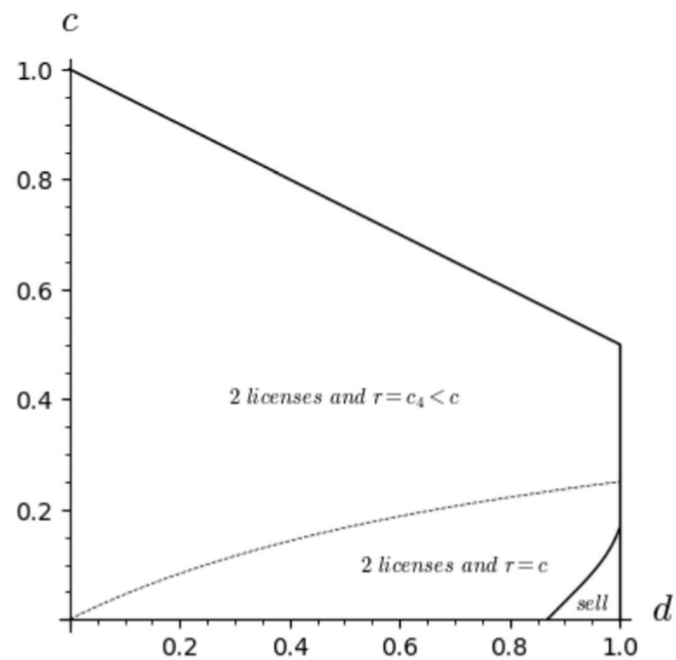

Fig. 5. Patentholder's decision on whether to sell or licence the innovation.

Proposition 3. *Let $c_5(d)$ be the size of the innovation that solves $B_1^V - \pi_1^n = \pi_{PH}^{l,R}$. The following holds:*

(i) *If the innovation size is such that $c \leq c_5(d)$, and the differentiation degree of the goods is such that $d \geq 0.85$, the innovation is sold to one of the firms in the industry, who then licences it to its competitor as shown in Proposition 1.*

(ii) *In any other circumstance, the innovation is directly licenced to both firms in the industry as shown in Proposition 2.*

According to Proposition 3, rather than retain innovation ownership and licence it directly, the patentholder prefers to sell the innovation to one of the industry's firms (that can subsequently licence it to its marketplace competitor) when the innovation is extremely minimal and the products obtained with the old and innovative technology are homogeneous or close substitutes. The explanation for this result is as follows. When the innovation is licensed (to both firms) by setting the per-unit royalty at the level of the innovation size (upper region of Fig. 4), the patentholder can achieve the profit of a multi-product monopoly. Since this situation is not reproducible when the innovation is sold to a single firm that subsequently licences it to its competitor by means of an ad-valorem royalty, the patentholder chooses to licence in this region. However, when the innovation is licensed by setting the per-unit royalty below the level of the innovation size (lower region of Fig. 4), industry profits are no longer at a maximum. Therefore, in this region, selling the innovation may be better than licensing when the degree of product differentiation is extremely low and the magnitude of innovation is very minimal. In this case, the redistribution in the outputs of both producers due to the ad-valorem royalty the assignee uses to licence the innovation to its competitor renders the industry close to a (homogenous) monopoly.

Fig. 5 depicts the result of Proposition 3 in the (d, c) region of admissible parameters. As shown in the figure, the patentholder only sells the innovation in a (tiny) region of parameters. Specifically, when the innovation is extremely minimal and the products are homogeneous or very close substitutes, leaving it to the assignee to further licence the innovation from within the industry. This region falls inside region (iii) in Proposition 1 and Fig. 3, where, when the patentholder sells the innovation, the assignee further licences it to its rival through a pure ad-valorem royalty. In the remaining region (covering almost all the admissible parameters), the patentholder prefers to directly licence the innovation to all firms as shown in Proposition 2 and Fig. 3.

Two lessons can be drawn from our results. First, in almost the entire region of admissible parameters (see Fig. 5), an outside patentholder prefers to licence the innovation to both firms in the industry rather than sell it (to a single firm in the industry). Only when the innovation is extremely minimal and products are very close substitutes does outright sale outperform licensing (i.e. the innovation is better monetised when sold to a firm that subsequently licences it to its rival through an ad-valorem royalty, compared with when it is licensed to both firms using per-unit royalties from outside the industry). Second, when the patentholder sells the innovation, the assignee always further licences it to its competitor in the product market; therefore, innovation diffusion is the same, regardless of the transfer method chosen by the patentholder. However, as we demonstrate in Section 6, the impact on market performance is considerably heterogeneous.

Our result in Proposition 3 corroborates Jeong et al.'s (2013) finding that outside patents are licensed rather than sold when uncertainty is low regarding risk and returns,[21] as happens in our (complete information) model. However, it sharply contrasts with the findings of Tauman and Weng (2012), Kabiraj and Sinha (2014, 2016), Sinha (2016) and Banerjee and Poddar (2019), who, for slightly different frameworks, found that outright sale generally outperforms licensing.

Tauman and Weng (2012) find that outright sale is strictly better than licensing for an outside innovator when the innovation is large enough, and a sufficiently high number of potential (symmetric) users of the innovation compete in the market. Our model demonstrates that this outcome persists, even with only two potential users but only when the innovation size is extremely minimal and the goods produced in the industry in which the innovation is marketed are homogeneous or very close substitutes. Conversely, in almost the entire admissible parameter space, licensing the innovation yields a more collusive industry than sale. Kabiraj and Sinha (2014, 2016) also found that sale is better than licensing but for a vertically related market where the patentholder is a downstream firm, whereas our model addresses a one-tier industry and an outside patentholder. In the context of potential innovation users with asymmetric costs, Sinha (2016) determined that an outsider patentholder prefers to sell the innovation only to the efficient firm, which does not licence it further, contrasting with our result for a context in which the innovation can be sold to any one of the firms and the assignee always licences it to the rival firm, irrespective of the innovation size. Therefore, our model results in a higher degree of technology diffusion than Sinha's framework. Finally, Banerjee and Poddar (2019) considered an outside patentholder facing asymmetric potential users that compete in a spatial framework (differentiated product–price competition), concluding that, regardless of the size of the innovation (drastic or non-drastic) and the cost asymmetry between licensees, the patentholder is always better off selling the innovation to a firm that further licences it to its competitor in the product market. Our model differs in that the potential users of the innovation compete by setting quantities, which shows the role that market competition (through prices or quantities) can play in how an outside innovation is transferred to the industry.

7. Welfare analysis and policy proposals

From the above analysis, we conclude that a cost-reducing innovation in the hands of an outside patentholder ends up being applied by all potential users in the industry, regardless of whether the patentholder chooses to sell the innovation outright or licence it. However, the welfare implications of outright sale and licensing for consumers and society at large may differ, given the different technology diffusion mechanisms operating in each case. Therefore, we next examine the welfare effects of the patentholder directly licensing the innovation versus selling the innovation to one of the firms in the industry on consumers and society as a whole.

To this end, we consider consumer surplus defined as $CS = (q_1^2 + 2dq_1q_2 + q_2^2)/2$, and aggregate welfare, W, measured as the non-weighted sum of consumer surplus and industry profits (including those of the patentholder), $W = CS + \pi_1 + \pi_2 + \pi_{PH}$. Since a debate exists over whether consumer surplus or social welfare should be used as a welfare standard for regulatory purposes[22] (Farrell and Katz, 2006; ICN, 2011; Kaplow, 2011; Blair and Sokol, 2013; OECD, 2023), and since the findings regarding each criterion are required for policymaking, it is essential to compare the results for each standard and understand how they differ.

Before the innovation is transferred to the industry (pre-transfer scenario), both firms use the initial technology and incur marginal cost c. In this context, the amount each firm i produces is $q_i = \frac{1-c}{2+d}$, $i = 1, 2$, whereby consumer surplus, industry profits and aggregate welfare respectively amount to the following:

$$CS = \frac{(1+d)(1-c)^2}{(2+d)^2}, \pi = \frac{2(1-c)^2}{(2+d)^2} \text{ and } W = \frac{(3+d)(1-c)^2}{(2+d)^2} \tag{24}$$

Furthermore, Proposition 3 indicates that the patentholder directly licences the innovation in the regions of parameters in which $0 \le d \le 0.85$ or $0.85 \le d \le 1$ and $c > c_5(d)$. Moreover, Proposition 2 indicates that licensing in these regions is made by using per-unit royalties that are lower than or equal to the cost reduction resulting from the innovation. Therefore, from the licensees' output levels in the post-transfer scenario given in Eq. (20), consumer surplus and industry profits amount to the following:

$$\left(CS^l, \pi^l\right) = \begin{cases} \left(\frac{(1+d)(1-c)^2}{(2+d)^2}, \frac{2(1+c+cd)(1-c)}{(2+d)^2}\right), \text{if } c \le c_4(d) \\ \left(\frac{1}{4(1+d)}, \frac{1}{2(1+d)}\right), \text{if } c > c_4(d) \end{cases}; \tag{25}$$

therefore, the total welfare achieved when the patentholder directly licences the innovation amounts to the following:

$$W^l = \begin{cases} \frac{3-2c-c^2+(1-c^2)d}{(2+d)^2}, \text{if } c \le c_4(d) \\ \frac{3}{4(1+d)}, \text{if } c > c_4(d) \end{cases}. \tag{26}$$

The alternative for the patentholder is to sell the innovation to a firm in the industry, who, as an 'insider', then licences it to its direct competitor, as stated in Proposition 1. This transfer method occurs when the innovation is sufficiently small, at $c < c_5(d)$, and the goods produced in the industry are close substitutes, at $0.85 \le d \le 1$, which are values within region (iii) defined in Proposition 1 (i.e. the region in which the

[21] Different monetization strategies for outside patents entail different risks and returns, and the most appropriate strategy depends upon the innovation's specific characteristics. Therefore, licensing, which implies royalties, tends to be a riskier strategy than outright sale, which implies the use of fixed-fee payments (Caviggioli et al., 2020).

[22] For example, EU, US and Japanese regulators predominantly rely on a consumer welfare standard (focusing on consumer surplus), whereas regulatory authorities in Canada, Australia and New Zealand tend to use a broader aggregate welfare (or total welfare/total surplus) standard (ICN, 2011; Blair and Sokol, 2013; OECD, 2023).

assignee, F1, uses a pure ad-valorem royalty contract). In this case, F1 and F2 will produce the equilibrium output levels given by $(q_1^s, q_2^s) = \left(\frac{2-(1+v^*)d}{4-(1+v^*)d^2}, \frac{2-d}{4-(1+v^*)d^2}\right)$, with the optimal ad-valorem royalty v^* as stated in part (i) of Lemma 2. Consequently, respective consumer surplus, industry profits and aggregate welfare amount to the following:

$$\left.\begin{array}{c} CS^s = \frac{(q_1^s)^2 + 2dq_1^s q_2^s + (q_2^s)^2}{2}, \\ \pi^s = (1 - q_1^s - dq_2^s)q_1^s + (1 - q_2^s - dq_1^s)q_2^s \\ \text{and} \\ W^s = q_1^s + q_2^s - \frac{(q_1^s)^2 + 2dq_1^s q_2^s + (q_2^s)^2}{2} \end{array}\right\}. \quad (27)$$

Finally, comparing Eq. (24) with Eqs. (25) and (26) and Eq. (27) enables us to obtain the following result regarding the welfare impact of an outside innovation's diffusion, either through outright sale or licensing.

Proposition 4. *Compared with the pre-transfer scenario, transfer of a cost-reducing innovation by an outside patentholder leads to the following:*

(i) *Consumer surplus decreases when the innovation is transferred through sale, whereas it remains unchanged (increases) when the innovation is transferred through licensing and the per-unit royalties used are lower than (equal to) the innovation size.*
(ii) *Industry profits increase, regardless of whether the innovation is transferred through sale or licensing.*
(iii) *Aggregate welfare rises, regardless of whether the innovation is sold or licensed by the patentholder.*

When the patentholder licences the innovation to both firms using a per-unit royalty lower than (equal to) the innovation size, industry efficiency improves (remains unchanged) and firms' production increases (remain unchanged). Therefore, although per-unit royalties over the zero marginal cost the innovation incurs are profitable because of their collusive effect on firms' market behaviour, the increased productive efficiency effect outperforms this collusive effect, and consumers end up paying a lower (equal) price than before the innovation was transferred. However, when innovation sale is profitable for the patentholder, the

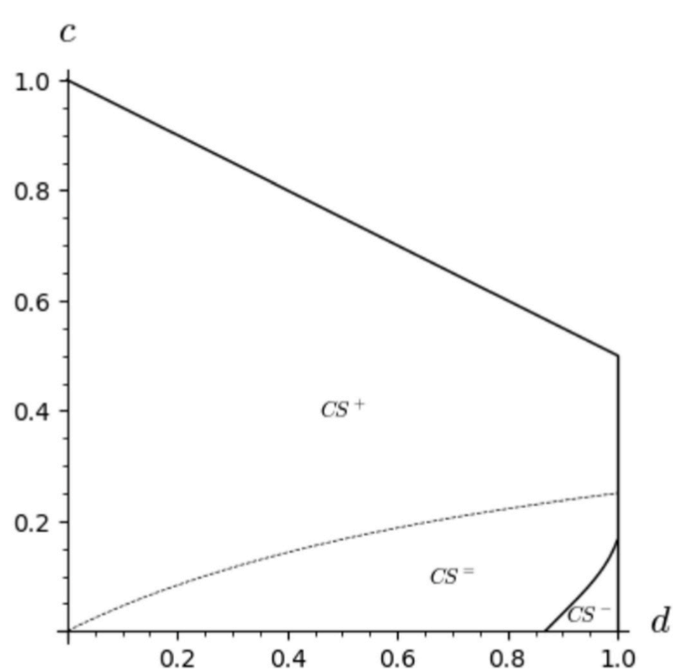

Fig. 6. Impact of innovation transfer on consumer welfare.

assignee subsequently transfers the innovation to its competitor by means of an ad-valorem royalty; this leads the quantities produced in the industry to become asymmetric (F1's production is reduced and F2's production is increased) and significantly decreasing overall, leaving consumers worse off than in the pre-transfer scenario.

Finally, from the perspective of society at large, innovation diffusion, whether through licensing or outright sale, increases aggregate welfare relative to the pre-transfer scenario. This is because the cost reduction the innovation incurs and the consequent increase in industry profits offset any reduction in consumer surplus that may emerge.

The result of Proposition 4(i), regarding how the patentholder's behaviour in terms of transferring innovation to the productive sector impacts consumers is graphically illustrated in Fig. 6.

The result of Proposition 4 sharply contrasts with Mukherjee and Sinha (2024), who showed that, regardless of whether market competition is quantity- or price-based, outside technology licensing may be welfare-reducing when it is a small innovation and the initial cost difference between its potential users is large. We obtain the opposite result for a context in which the potential innovation users are initially cost-symmetric, the patentholder can transfer the innovation by choosing between licensing or sale, and royalties involved in licensing contracts may be of per-unit or ad-valorem type. Our result also differs from Faulí-Oller and Sandonís (2002), who characterised scenarios in which inside technology licensing to a rival firm by means of a 2PT contract featuring per-unit royalty is welfare-reducing. In our case, licensing by an internal licensor (the assignee) is welfare-enhancing because the assignee applies an ad-valorem royalty and the resulting reduction in consumer surplus is more than offset by increased industry profits.

Therefore, observing our result, the question is what public policies should a regulator adopt to ensure that consumer surplus never decreases with outside technology diffusion, regardless of the patentholder's behaviour in diffusing it? If we assume second-best non-interventionist policies, i.e. measures in which the policymaker (i) does not intervene in firms' quantity choices (as considered in this study), (ii) does not intervene in the royalty rates that the patentholder can choose (beyond prohibiting clearly collusive tariffs such as negative fee payments, $f < 0$, in any 2PT deal) and (iii) does not force the patentholder to sell the innovation when it prefers to licence it, then two alternative policies can be considered.

The first alternative is to prevent the patentholder from selling the technology, leaving licensing as the sole means for transferring it to the productive sector. Such a policy would lead the patentholder—in the parameters region in which it would prefer to sell the innovation in a laissez-faire scenario, and according to Lemma 4 and Proposition 2—to licence the innovation to both firms by means of 2PT contracts involving per-unit royalties equal to the innovation size. Consumer surplus would be unaffected and industry profits would increase (compared to a non-licensing scenario), although the patentholder's profit and total welfare would decrease (compared with the innovation sale scenario). In addition, a regulator concerned about consumers (consumer-oriented regulator) could prevent patentholders' joint venture with a firm in the industry, takeover by or merger with an incumbent firm.

The second alternative would be to allow the patentholder to sell its technology but prevent the assignee from licensing it to direct rivals in the industry. This policy would motivate the patentholder to change its monetising strategy, which would then consists in licensing the technology to both firms in the entire region of parameters, rather than sell it to one of them in a small subregion as indicated by Proposition 3 (see Fig. 5). Notably, since Proposition 2 indicates that the patentholder would obtain more profit from issuing two licences, both policy alternatives—prevent the patentholder from selling the innovation or prevent the assignee from licensing the innovation—would ultimately produce the same outcome in terms of the patentholder's choice and would therefore have the same impact on consumer surplus and aggregate welfare.

In summary, when designing regulatory measures in relation to technology diffusion from outside the industry, the main lesson that can be drawn from our model is that the magnitude of the innovation and the specific details of the industry in which it is used (specifically, the degree of differentiation of the goods produced with the technology) are crucial factors to consider.

8. Conclusions

We examine the problem of an outside, non-producing patentholder that, seeking profit from a cost-reducing innovation, needs to transfer it to one or more established firms with the capacity to produce a final good with the innovation. The commercialising strategies available to the patentholder are outright sale and licensing, and the industry in which the innovation can be exploited is a Cournot duopoly wherein firms produce horizontally differentiated goods with the old and new technology. If the patentholder sells the innovation, the ownership rights are transferred, and the assignee can further licence the innovation to its competitor through a specific licensing deal that may involve a fixed-fee payment combined with a per-unit or ad-valorem royalty. Alternatively, if the patentholder directly licences the innovation, it can do so by means of a 2PT contract involving a fixed-fee payment combined with a per-unit or ad-valorem royalty, as when the assignee licences.

In this context, we find that, when the cost reduction the innovation leads to (innovation size) is extremely minimal and the goods produced with the old and new (improved) technology are homogeneous or very close substitutes, the patentholder prefers to sell the innovation to one of the firms in the industry, which further licences it to its market competitor through an ad-valorem royalty contract. Under any other circumstances, the patentholder prefers to retain ownership of the innovation and licence it to both firms through 2PT contracts shaped as a fixed-fee payment combined with a per-unit royalty. Therefore, considering the optimal conditions for maximising the economic value of an outside innovation, direct licensing is superior to outright sale in almost the entire admissible parameter space of our model, indicating that the predominant means of transferring such an innovation to the productive sector should be licensing from outside the industry, rather than sale. Even in the case of outright sale, subsequent licensing by the assignee to its marketplace competitor (inside licensing) should occur. The rationale for this result is that licensing the innovation to both firms in the industry, rather than selling it to one of the firms, enables the patentholder to better replicate a multi-product quasi-monopoly in the industry (i.e. a quasi-monopoly that produces two goods). This result sharply contrasts with previous findings in the extant literature that, in slightly different frameworks, show that outright sale is preferable to licensing (Tauman and Weng, 2012; Kabiraj and Sinha, 2014, 2016; Sinha, 2016; Banerjee and Poddar, 2019). In our model, outright sale, followed by subsequent licensing by the assignee, only outperforms direct licensing in a very small region of parameters, where the innovation is extremely minimal and the goods produced with old and new technology are homogeneous or considerably close substitutes. However, if the formation of a joint venture between the patentholder and one firm in the industry is understood as innovation sale, our result aligns with Anand and Khanna's (2000) finding that, on average, a joint venture generates shorter excess returns than licensing, and Jeong et al.'s (2013) finding that when uncertainty is low, patentholders tend to prefer to licence their patents rather than sell them.

Similarly, except in the lower region of parameters where the innovation size is sufficiently small and products are homogenous or very close substitutes, yielding a transfer by sale, the subsequent technology diffusion is welfare-enhancing. The implication of this finding is that a public policy that incentivises non-producing patentholders to licence (retain ownership rights) rather than sell their cost-reducing innovations would be socially desirable. In a sense, this policy can be interpreted as discouraging outside patentholders from entering joint ventures with manufacturing firms as a means to exploit their innovations by licensing them to direct competitors from within the industry.

In summary, in offering fresh insights into technology transfer mechanisms commonly used in the real world, our findings enrich the understanding of the choice between outright sale and licensing of cost-reducing innovations owned by non-producing patentholders. Furthermore, our findings offer two promising directions for future study. First, the current model does not consider the potential impact of price-based rather than quantity-based competition in the product market between the potential users of innovation on the patentholder's behaviour. Extending the model to examine the optimal transfer of an outside innovation when the potentially interested firms are Bertrand instead of Cournot competitors would enable us to determine the influence of greater marketplace competition intensity on innovation transfer methods and their welfare impact. Second, our framework assumes that the potential innovation users compete in a one-tier industry. However, it could be the case that potential applicants need to acquire an essential input from an upstream supplier (e.g. raw materials or components) to exploit the innovation, in which case a two-tier industry would emerge. In this setting, when deciding how to transfer the innovation, the patentholder should not only consider the practices of downstream industry in which the innovation is implemented but also those of the input supplier in the intermediate market. Therefore, extending the analysis to incorporate a vertical industry may also improve the realistic application of our model and yield richer implications for practitioners and policymakers involved in technology transfers (i.e. stakeholders focused on bridging the gap between the result of research and development activities and the effective technological diffusion). We leave these extensions for future research.

Author contributions

Both authors contributed equally to this work.

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Declaration of competing interest

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