Patents v. Open Source: What is the socially optimal way to secure IP payments when innovation is uncertain?

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Preliminary Version

1. Introduction

a. General

- We consider cases of intellectual property (IP) over an invention that cannot be directly consumed, requiring instead additional R&D in order to yield a final product that can respond to consumer desires.
    - Very often this additional R&D must be carried by developers (*D*) other than the patent holder.
- An example central to our motivation, is that of patented plants obtained through genetic editing.
    - Usually, these plants require that their traits be assembled with other traits before yielding marketable products;
    - this part of the final product's development must usually be carried out by special breeders, outside the firm that has invented the genetically modified basic plant.
    - Each breeder usually develops a unique differentiated product and has exclusive rights upon its commercial exploitation.
    - Breeders may themselves be patent holders selling IP rights to other breeders.

- Modern economics consider the protection of IP as a *sine qua non* for innovation, offering to the innovator monopoly rights for a given period.
    - The ***patent protection*** system (*PP*) grants the patent holder (*Ph*) the right to limit the use of his innovation to those he wishes (exclusion right).
    - In an ***open source*** (*OS*) system the *Ph* the patent holder sets a royalty and lets all the potential users free to decide whether to use the innovation, provided that they pay the required royalties
    - Thus, we interpret
        - the traditional *PP* as a two-part tariff, where the *Ph* may ask for a fixed payment associated to the right to use the innovation and a royalty related to proceeds stemming from the use of his innovation;
        - the *OS* as a linear tariff, where the *Ph* can only determine a royalty

b. Plant v. Plant-variety, some legal issues

- A ***Plant*** is a general category based on common essential genetic characteristics.
- A plant gives rise to several ***Plant Varieties,*** differing among them according to some complementary genetic characteristics
- Final products are characterized as ***varieties***.
    - If not defined as Variety, a Plant cannot be directly sold to consumers
- In our model, the *Ph* holds IP over a plant that cannot be directly commercialized before a breeder turns it to a plant variety.

- ***Plants*** are protected by patents
- ***Plant varieties*** are protected by patent in some countries or by the PVP system in EU.
    - The PVP protects
        - the propagating material (*e.g.*, seed cuttings, divisions, etc.)
        - the harvested material (*e.g.*, cut flowers, fruit, foliage, etc.)
    - What the PVP does not grant is ***exclusivity over the genetic resources*** of the variety:
        - access to the *genetic material* of a protected variety is ***free and free of charge***.
            - Patent confers ***full*** exclusivity to the owner of a variety whereas
            - PVP protection offers only ***partial*** exclusivity.

- It has been argued that as a consequence,
  - patenting protects the owner of a PV but discourages the development of new PVs
  - PVC encourages the development of new varieties but does not provide adequate rights to the PV owner

- An intermediate solution has been proposed by several lawyers (see Van Overwalle, 2018):
  - *Protect both plants and plant varieties by an open source (OS) protection that allows the access to the genetic material of a protected plant to* ***be free, but not free of charge****.*
- Important institutions such as the INRA-E in France openly support the replacement of a patent system by an OS one.

- In this work we want to investigate whether compared to a traditional *PP* system the open-source protection (OS) encourages the development of greater plant variety
    - Thus, we investigate
        - Whether the L or the TP produce greater incentive for further PV development
        - The welfare properties of the two systems

2. The Model

a. Downstream market

- There is uncertainty over the development of a new product
- If successful, developer *i* is a monopolist facing a linear demand of the form

$$q_i = 1 - p_i$$

  - In case of failure, the quantity demanded is zero at any price
- The probability of success is 1/2
- No variable production cost
- A fixed R&D cost *F* must be paid before the uncertainty is resolved;
  - ***F* is not recoverable in case of failure**
- In case of PP, on top of any “real” costs, a D may also have to pay IP rights to the Ph.
- Under the above assumptions, the market is worth only if:

$$F \geq \bar{\bar{\bar{F}}} = 0.125$$

b. Ds' utility

- Each D is characterized by a risk aversion parameter $\varphi_i \in [0, \Lambda]$ and has utility

$$U_i = \hat{\pi}(w) - F - T - \varphi_i \sigma^2$$

where:

- $\hat{\pi}$ is the expected gross profit from a successful R&D
  - $\hat{\pi}$ depends on the royalty $w \geq 0$ charged by the Ph
- *T* is any fixed payment required by the Ph in order to allow exploitation of his patent
- $\varphi_i = \underline{\lambda} + \lambda_i$ is the risk-aversion coefficient
  - $\underline{\lambda} \geq 0$ is a shift parameter (more about that later)
- σ^2 is the profit variance between the states of success and failure

- A common problem with the mean-variance utility function is that it may not respect 1st order stochastic dominance.

- This may happen when a *D* is so risk-averse as to prefer *ceteris paribus* lower returns in case of success in order to reduce the variance

- We rule this out by imposing an upper bound on the risk-aversion coefficient such that

$$\frac{\partial U_i}{\partial w} < 0, \quad \forall i,$$

which implies

$$\varphi_i = \underline{\lambda} + \lambda_i \leq \frac{-\frac{\partial \pi}{\partial w}}{\frac{\partial \sigma^2}{\partial w}}$$

- Under our simplifying assumptions,

$$\underline{\lambda} + \lambda_i \leq 4 \qquad (dPer\ condition)$$

c. Upstream market

- The basic invention has been already obtained and there is no variable of fixed cost in making it available to Ds

- The Ph offers a take-it-or-leave-it contract to all Ds. This contract can be either

  - linear (*L*) consisting of a variable payment w_1 per unit of final product sold (royalty), or

  - two-part tariff (*TP*) consisting of a variable payment w_2 and a fixed payment *T*

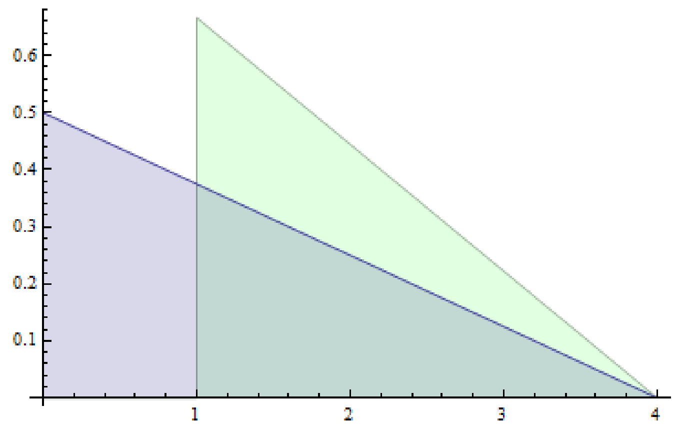
- Note that

  - Royalties are paid ex-post and only in case of successful product development

  - the fixed payment *T* in case of a TPT, is paid ex-ante

d. Developers' distribution

- The Ph maximizes profit considering that he faces a distribution of Ds according to their risk aversion
  - We assume a triangular decreasing distribution on the interval $[\underline{\lambda}, \underline{\lambda} + \Lambda)$ with mode at $\underline{\lambda}$.
  - Λ is the width of the distribution



  - This implies a decreasing distribution with probability density and cumulative density function, respectively:

$$g(\lambda) = \frac{2(\Lambda - \lambda)}{\Lambda^2}, \qquad G(\lambda) = \frac{\lambda(2\Lambda - \lambda)}{\Lambda^2},$$

- The presence of $\underline{\lambda}$ allows us to bound the risk-aversion coefficient from below away from 0.
- This is particularly important since the mode is at the beginning of the distribution: letting $\underline{\lambda} = 0$ is a good start for it gives the simplest solutions, but implies that the majority of Ds are situated close to risk-neutrality, a rather unrealistic assumption
- In order to respect the *dPer* condition (1st order stochastic dominance) it must be that

$$\underline{\lambda} + \Lambda \leq 4$$

and in order to avoid trivial cases, that

$$\underline{\lambda} \in [0,4)$$

3. Equilibrium

The basic invention has been already obtained and there is no variable of fixed cost in making it available to Ds.

Patent Protection (PP)

- Under PP, the Ph uses TP and his program can be summarized as:

$$\max_{\{w,T\}} \Pi_2 = G(\lambda_2(w,T); \underline{\lambda}, \Lambda, F) * (w\hat{q}_2 + T)$$

$$\text{sub. to} \quad U(\lambda_2) \geq 0$$

- Setting the constraint to hold with equality, replacing $U(\lambda_2)$, and solving for T, we obtain:

$$T = \hat{\pi}(w) - F - (\underline{\lambda} + \lambda_2)\sigma^2$$

- By replacing the above in the objective function, we can use λ instead of T as choice variable.
- Considering also the triangular density function's characteristics, Ph's maximization program becomes:

$$\max_{\{w_2,\lambda_2\}} \Pi_2 =$$

$$\frac{\lambda_2\left[8(-8F+(1-w_2)^2)-16(-1+w_2)w_2-(1-w_2)^4(\underline{\lambda}+\lambda_2)\right](2\Lambda-\lambda_2)}{64\Lambda^2}$$

b. Open source (OS)

- Under OS, the Ph uses L tariff. If for a given level of Λ, F is sufficiently small (or, for a given level of F, Λ is too narrow),
  - the Ph sets $w = \frac{1}{2}$ and sells to all the *D*s.
    - The Ph's problem has a corner solution and all the *D*s have positive profit.
- As F increases, some of the *D*s drop out and the Ph must consider reducing *w* in order to obtain more clients.
  - Now, the Ph must choose *w,* knowing that a reduction in *w* lowers revenue per *D* while increasing the number of *D*s that invest.
    - Now, the Ph's problem has interior solution but the marginal *D* has zero profit.

- Let λ_1 be the most risk-averse *D* who invests. By solving the constraint $U(\lambda_1, w) = 0$, we obtain:

$$\lambda_1 = \lambda_1(w)$$

  - substituting it back to the profit function we have

$$\max_{w} \Pi_1 = G(\lambda_1(w); \underline{\lambda}, \Lambda, F) * (w\hat{q}_2),$$

provided that either F is sufficiently large, or Λ sufficiently narrow to yield $\lambda_1(w) \leq \underline{\lambda} + \Lambda$.

4. Analysis

Obviously, there is no hope to obtain analytical solutions in either problem type.

Hereafter, we proceed numerically.

Let the relative coverage be in each case

$$l_i = \frac{\lambda_i - \underline{\lambda}}{\Lambda} \in [0,1], \quad i = 1,2.$$

The following lemmata investigate the value of the royalty.

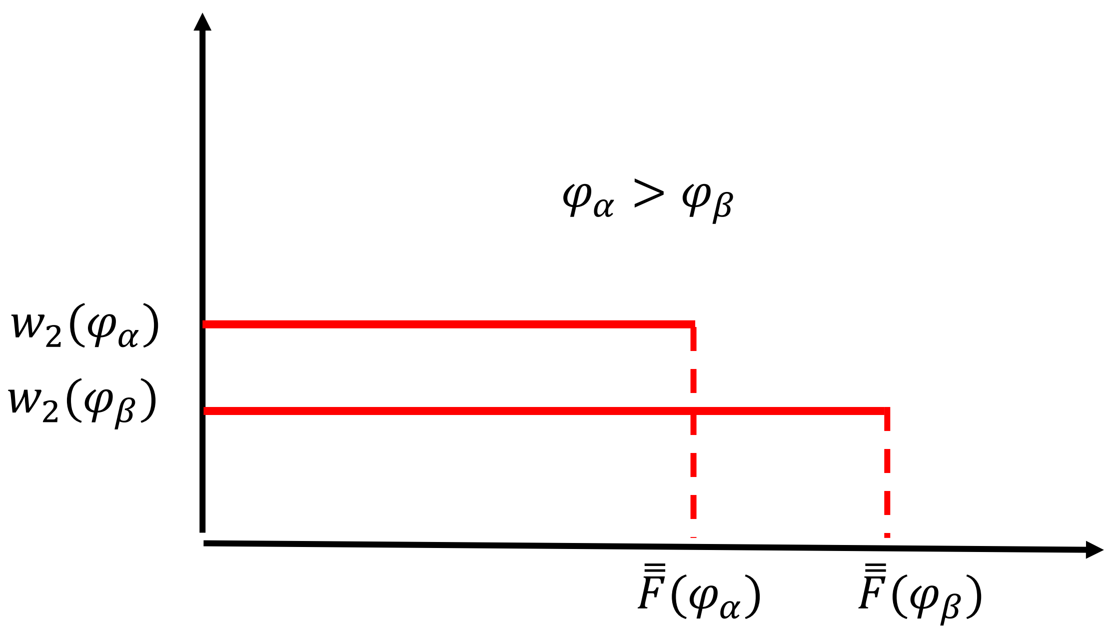
Lemma 1 *(**single D**)***:** *Assume a single D with given risk-aversion coefficient $\varphi > 0$. Under uncertainty, the optimal royalty contained in a TP tariff is*

above marginal cost,

constant over F, and

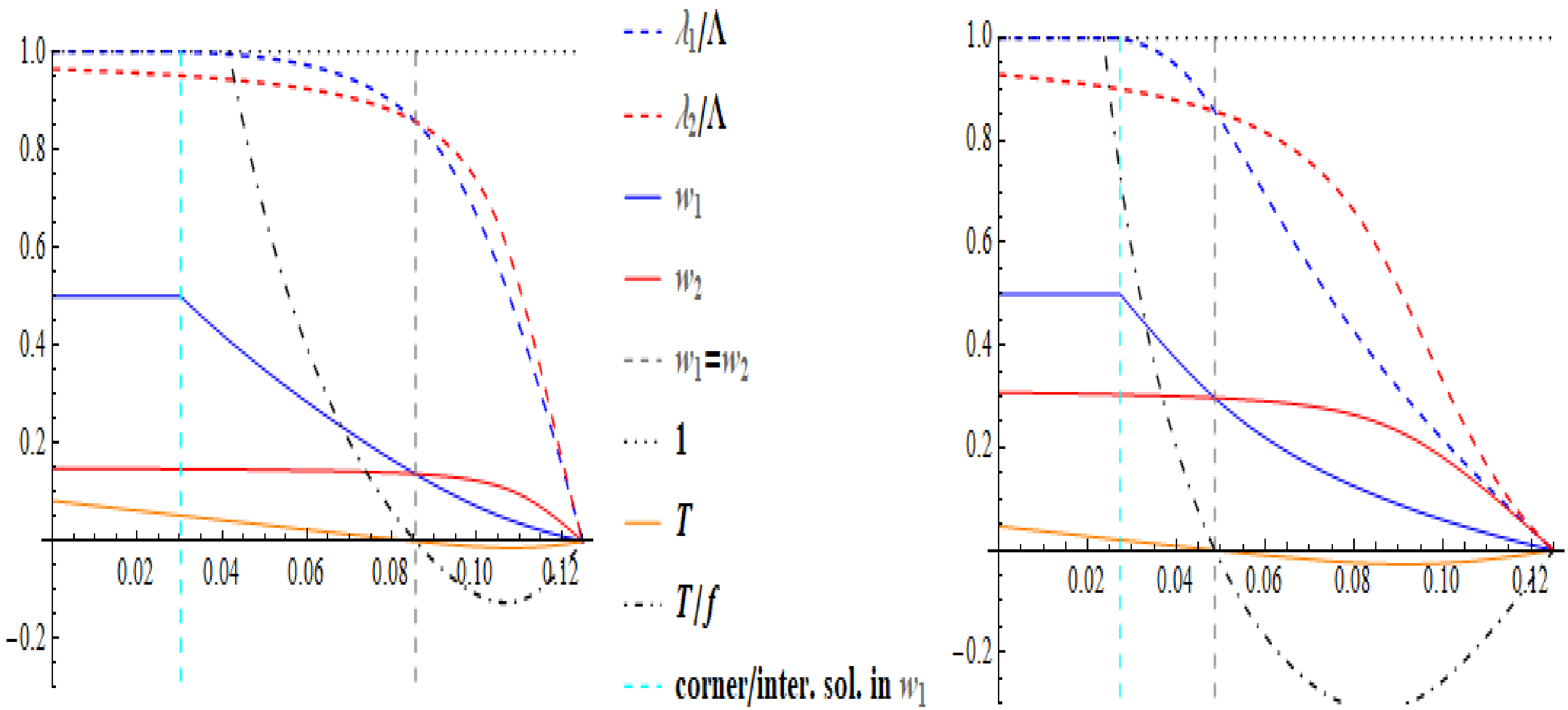
increasing in φ.

(see Constantatos and Pinopoulos, 2023, and Lomo 2022)



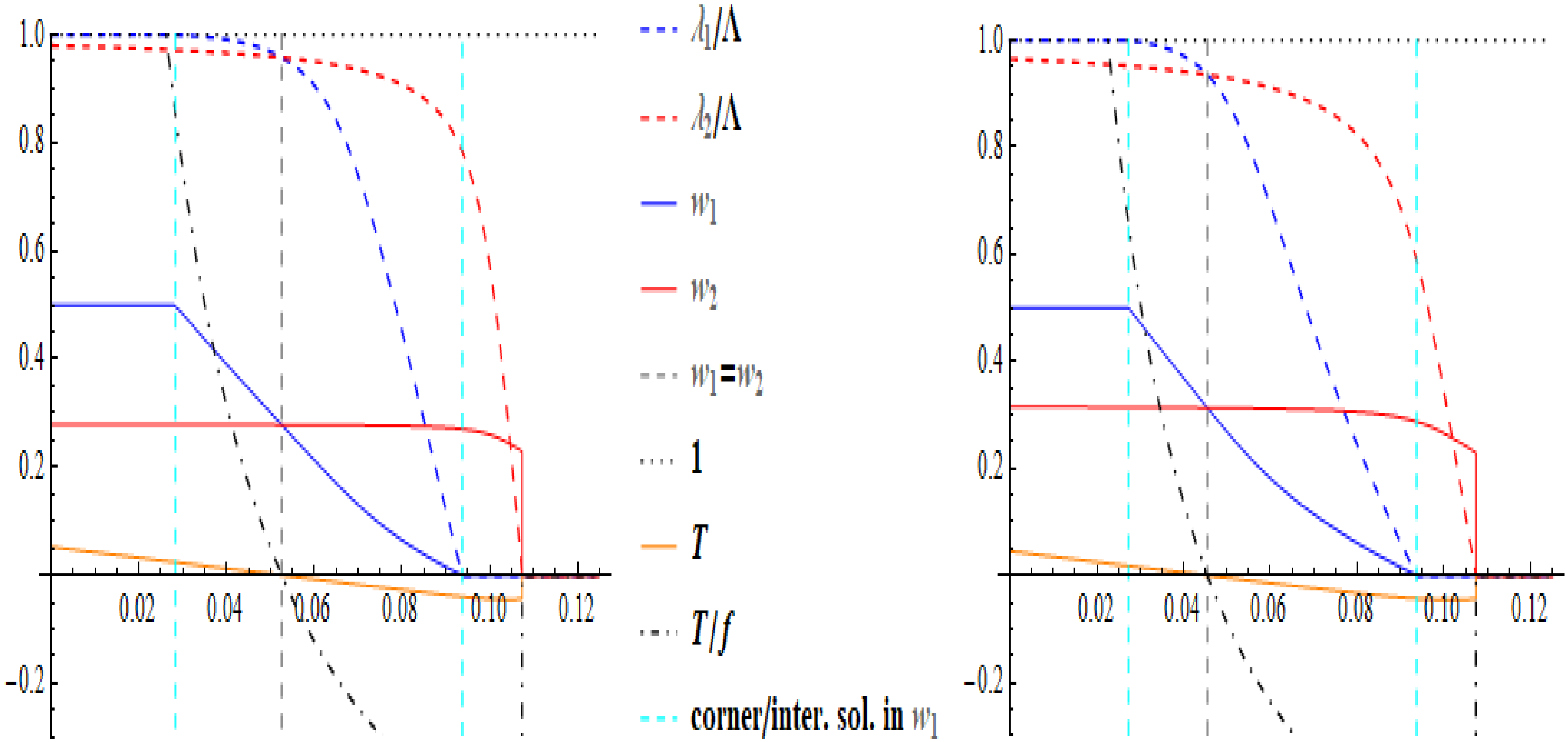
$\underline{\lambda} = 0$

$\Lambda = 1$ $\Lambda = 4$



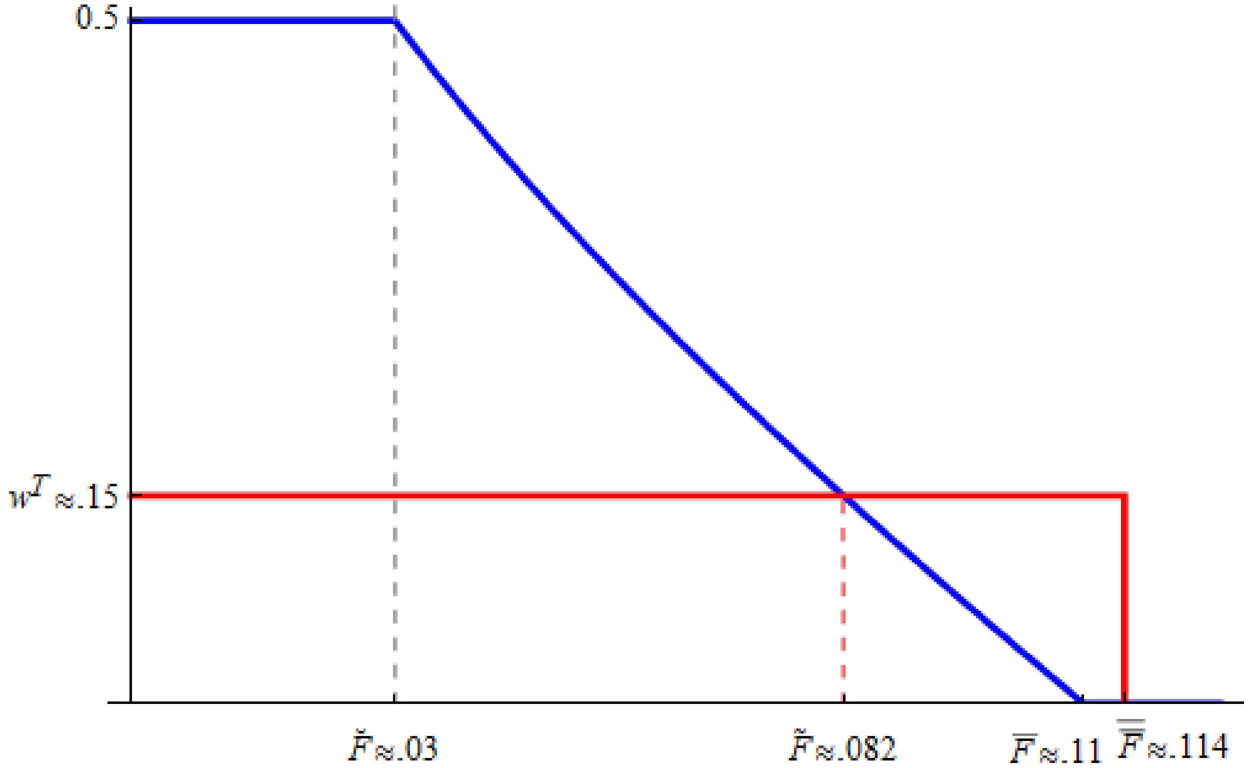
$\underline{\lambda} = 2$

$\Lambda = 1$ | $\Lambda = 2$



➢ **Single agent with $\boldsymbol{\lambda = 1}$**: Royalty Comparison between TP and L

Blue line: Input price under Linear tariff **Red line: Input price under Two-Part tariff**

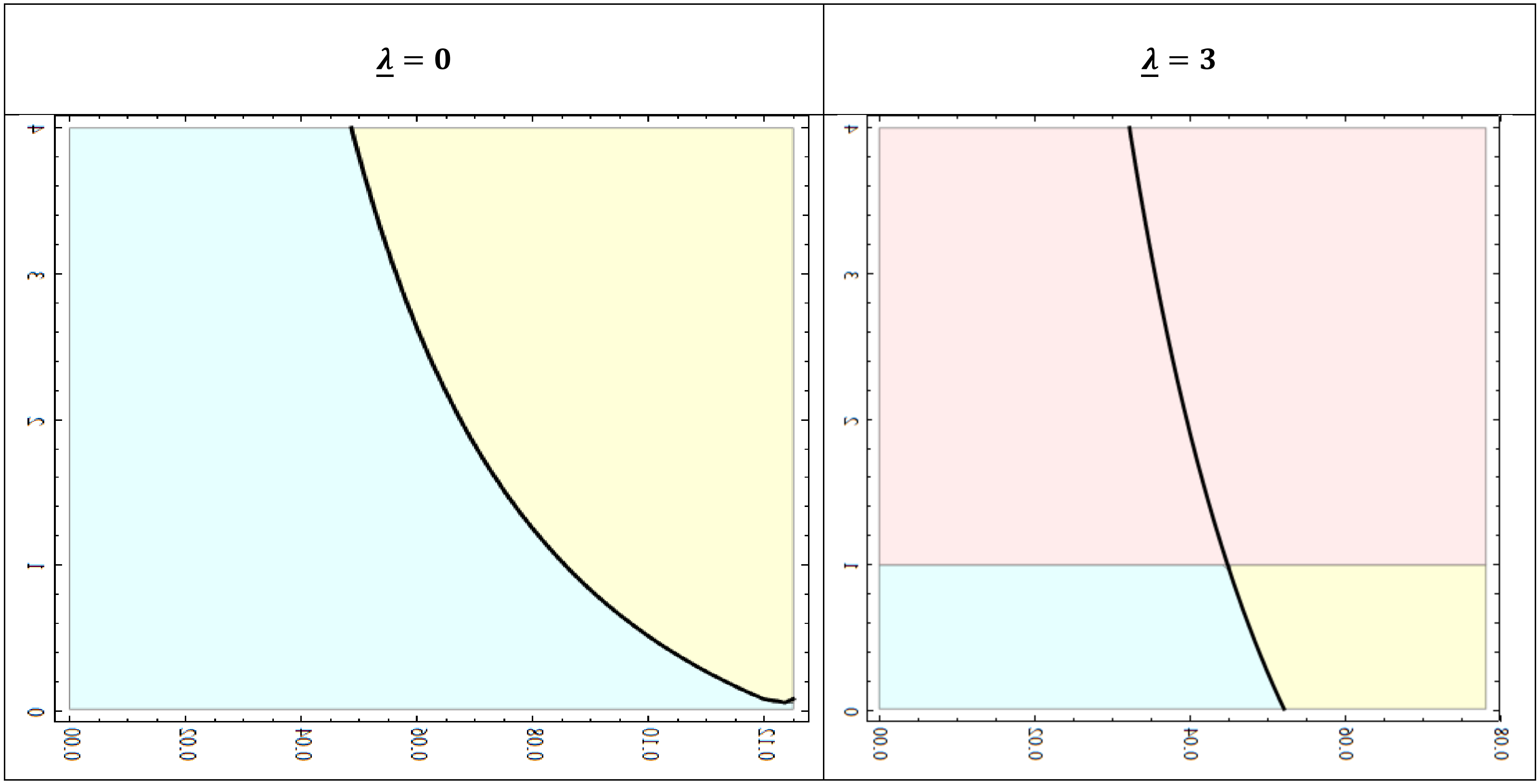


• As F increases, under TP the Ph accommodates the situation by lowering F, whereas under L by lowering w (the only variable he controls)

Proposition 1: *Let* $\underline{\lambda} \in [0,4)$, $\Lambda \in (0, 4 - \underline{\lambda})$ *and* $F \in (0, \overline{F})$.

- *i) For any given* $\underline{\lambda}$ *there is a locus of points on the* (Λ, F) *space, call it H, along which* $w_1(F, \Lambda; \underline{\lambda}) = w_2(F, \Lambda; \underline{\lambda})$;
- *ii) The H locus is monotonically decreasing and convex, dividing the space of admissible* (F, Λ) *values in two regions: region I and II, such that in region I (II):*
  - $w_1 > (<) w_2$
  - $T > (<) 0$.
- *iii) While for every admissible value of* Λ *there exists a value* $F_H(\Lambda)$ *such that the pair* $(\Lambda, F_H(\Lambda)) \in H$, *the reverse is true only when* $\underline{\lambda} = 0$;
- *iv) the H locus is displaced upwardly with increases in* $\underline{\lambda}$.

The proposition is illustrated on the following figure.



Horizontal axis: F. Vertical axis Λ (width).

The cyan area depicts region I where $T > 0$ and the classical relation $w_1 > w_2$ holds.

In the light-yellow area (region II), $T > 0$ and $w_1 < w_2$ (subsidization).

The pink area represents values of (F, λ) that do not respect stochastic dominance.

5. Welfare Comparisons

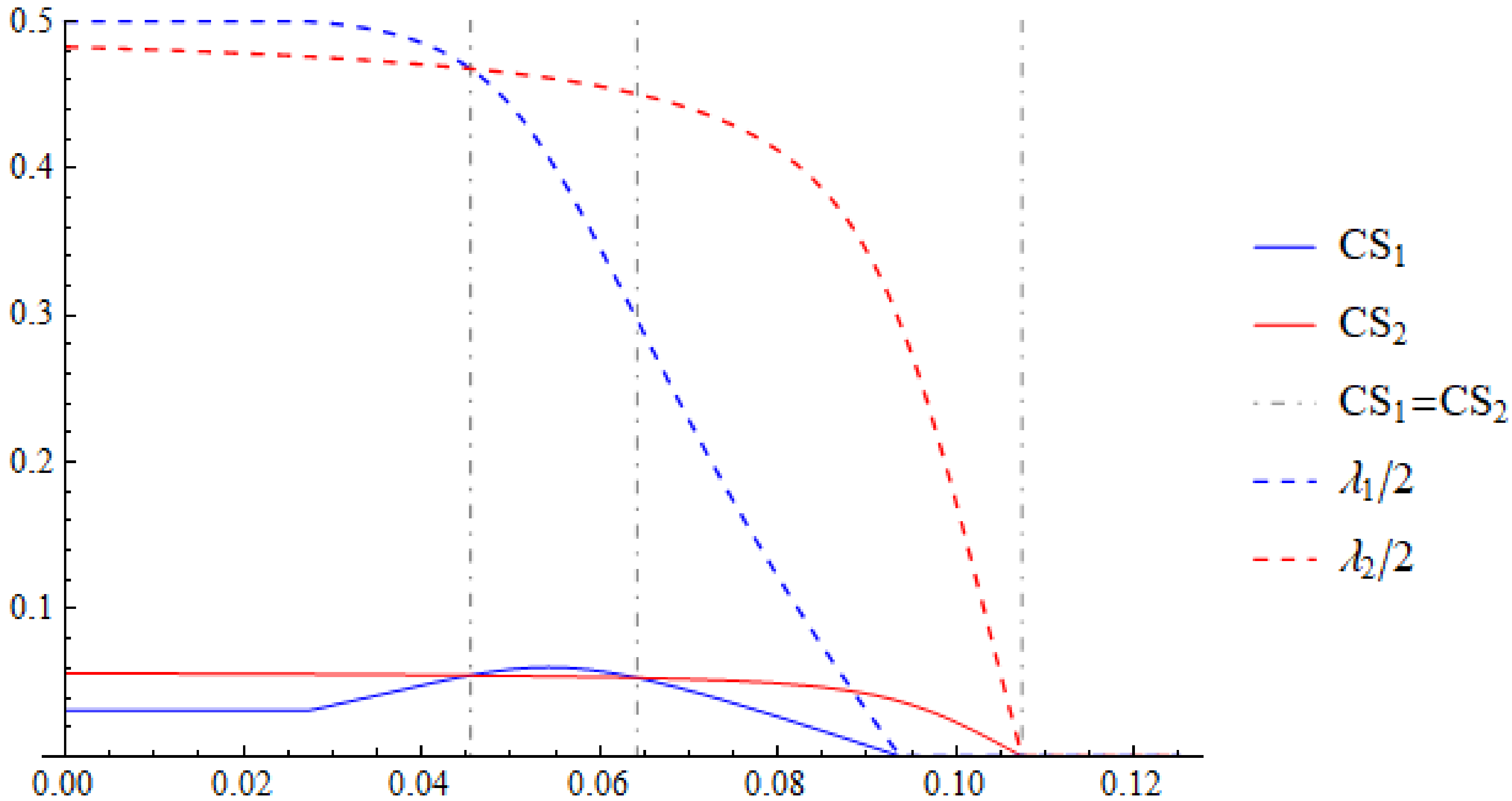
- Which system produces higher welfare?
- We have used three measures of welfare:
  - Expected consumer surplus
  - Expected brut social surplus (the area under the demand curve) and
  - Expected net social surplus.
    - The latter contains the fixed cost of the n-markets as well as the cost of risk.

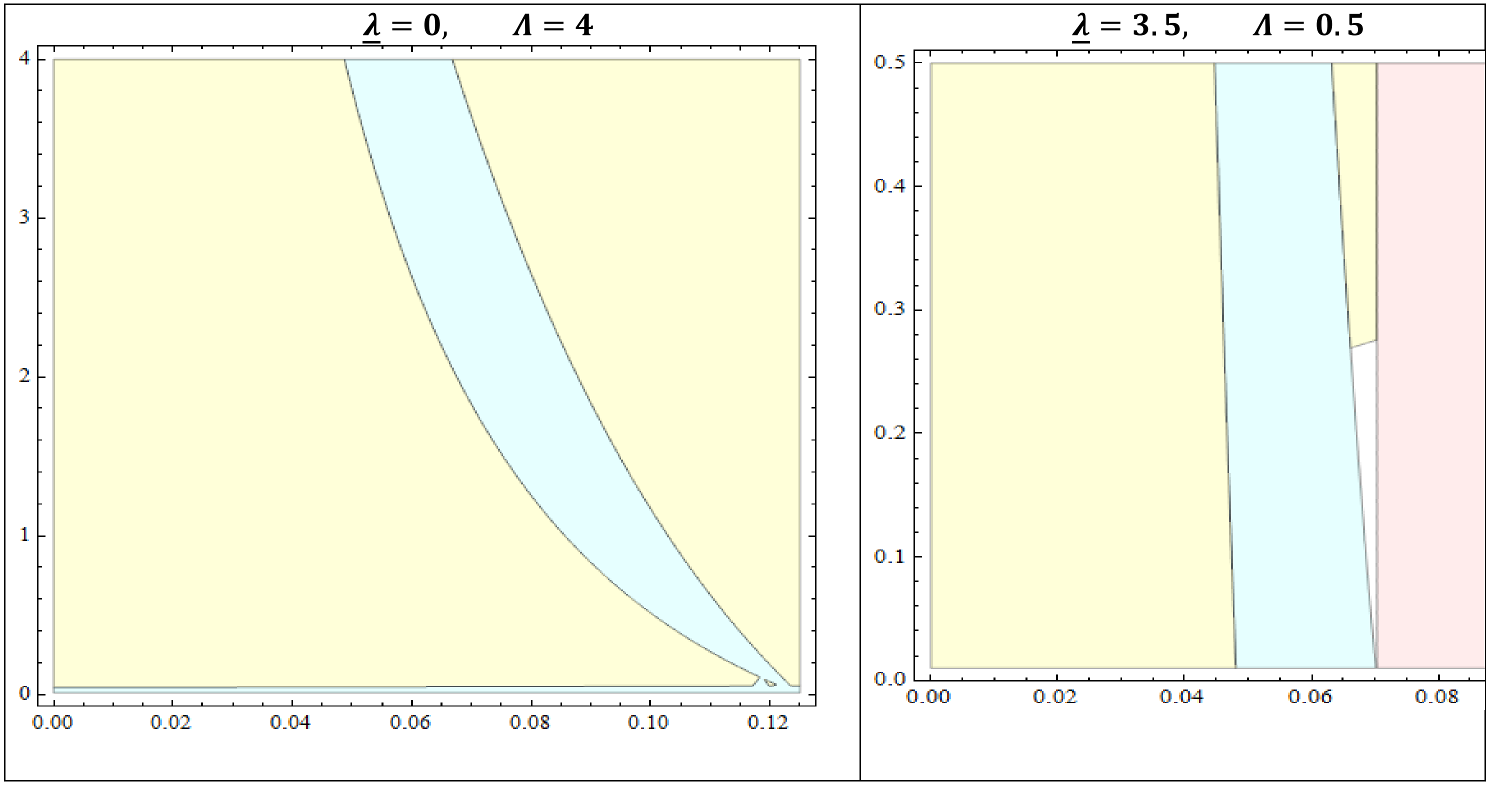
- Two effects:
    - Per-market surplus (lower *w*)
    - Number of markets (higher coverage, *l*)
- Recall that:
    - ➢ in region I (cyan) the TP tariff results in both, lower *w* and *l*.
        - OS creates a larger expected number of products but the PP yields more surplus per market.
    - ➢ in region II (yellow) the L tariff results in both, lower *w* and *l*.
        - OS creates higher surplus per market but it is the PP system that yields more products, if subsidization is feasible.

Overall effect?

- We concentrate on consumers surplus (total surplus and net welfare give similar results). The answer is again numerical, however, keep in mind that:
  - At low *F* levels, both systems produce a large number of products and *w* is high
    - The welfare impact of an increase at the *extensive* margin is **small** relative to an increase at the *intensive* margin (surplus per market).
      - **PP has a relative advantage**
  - At high levels of *F* both systems produce a small number of products and *w* is already low under both L and TP tariff.
    - The welfare impact of an increase at the *extensive* margin is **large** relative to an increase at the *intensive* margin (surplus per market).
      - **PP has again a relative advantage**
  - The OS produces more welfare only at a medium range of values of *F*.
    - Curiously, the OS is welfare superior in regions where PP subsidizes research and creates more products.

The results are illustrated on the next two figures:




$\underline{\lambda} = 0, \quad \Lambda = 4$
$\underline{\lambda} = 3.5, \quad \Lambda = 0.5$
0.00 0.02 0.04 0.06 0.08 0.10 0.12
0 1 2 3 4
0.00 0.02 0.04 0.06 0.08
0.0 0.1 0.2 0.3 0.4 0.5

6. Conclusions

- We compared two systems of IP protection: the traditional PP and the proposed OS.
    - We identified the first as a TP tariff and the second as mandatory L tariff
- The main argument for the introduction of OS is that it induces more Developers (breeders in the case of plants) to invest in R&D effort.
- We showed the argument to be valid, but only when the risk is low (small loss, *F*, in case of failure). In this case, the insurance provided by the ex-post payment of royalties does attract more *D*s, even if the marginal *D* makes no surplus under any system.
- However, for higher levels of *F*, it is optimal for the Ph to ***subsidize*** part of the R&D (***never the entire amount***) and collect its profits though higher royalties. In such a case, the PP system attracts more developers

- Welfare-wise there are two opposite effects: surplus per market (intensive margin) and number of markets (extensive margin). When F is low (high) the extensive effect is low (high).
    - Hence, the PP has in both cases (low or high F) the most valuable advantage.
    - However, for intermediate values of F, the OS creates more welfare.
- All our results are (for the moment) proven numerically but they are extremely robust.

- Further research is needed to
    - Establish the results analytically
    - Our present representation is limited, due to the fact that it does not allow cumulative interactions among breeders, a key point in favor of OS (the creation of libraries of genetic traits, available to all).
        - This would require extending the analysis to more than two stages of production.
        - It would allow to study more adequately the role of OS in allowing the exploitation of positive externalities in allowing many breeders to use the genetic traits of plants.
            - The possibility that those externalities are large is underlined by the use of OS in the programming industry, where sometimes codes are given for free, in order to generate improvements over the initial code.

Gracias por su atención