Regulating transgenic soybean production in Argentina

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Abstract

This article investigates how to regulate transgenic soybean production in Argentina. Taking into account the broad range of negative externalities associated with transgenic soybean production, we explore the effects of two different policy instruments, namely a subsidy for non-transgenic soybean and production quotas for transgenic soybean. Taking into account the political and economic context in Argentina, we demonstrate that auctioned production quotas are the best way to achieve the regulation of transgenic soybean production. However, the organization of the agricultural sector in Argentina is such that "raising rivals' costs" behavior could occur on the quota market although the output price is set exogenously. We show that auctioned quotas limit this anti-competitive behavior. Finally, we demonstrate that introducing a shadow cost of public funds leads to an increase in the optimal production level of transgenic soybean.

Keywords

Transgenic soybean, Argentina, Glyphosate, Environmental regulation, Production quotas, Market power.

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1 Introduction

Nowadays, farming in Argentina is under great pressure to meet environmental targets because the adoption of genetically engineered crops with specific traits for pest management has expanded at an impressive rate, in particular for soybean. According to the FAO database (FAOSTAT), this crop now represents 58% of total cultivated land and 38% of agricultural production, compared with 30% and 24% respectively in 2000. The oilseeds sector has thus gradually become a strategic sector of Argentina's economy and its remarkable productive performance has been the source of great pride.

However, the change in the structure of agricultural production has caused a wide variety of damage in terms of agricultural practices, emission of pollutants, human health and welfare. As a result, the long-term sustainability of Argentina' sspecialization in transgenic soybean production became a matter of concern during the first decade of the 2000s. The most controversial issue concerns the environmental impacts of transgenic soybean cultivation, such as the intensification of agricultural land use, incomplete crop rotation patterns, expansion of the agricultural frontier at the expense of natural lands, and above all, the intensive use of glyphosate. This herbicide, which regulates weeds growth, causes soil contamination, air and water pollution, and health problems (Gras and Hernández, 2009; Gras, 2009; Leguizamón, 2013; Pengue, 2005). Transgenic soybean cultivation also has a social cost: a significant amount of labor has been displaced out of the agricultural sector, and local rates of unemployment and income inequality have increased in the production zones (Phélinas and Choumert, 2017). Promoting a more sustainable agriculture in Argentina has become a necessity which, for many reasons we develop in Section 1, has not yet been given adequate attention.

Different regulatory approaches have been proposed in the literature when the damage comes from a large number of farms making cropping decisions (Griffi n and Bromley, 1982; Segerson, 1988; Helfand and House, 1995; Shortle and Horan, 2001). Most of them focus on input taxes, input levels, and farming practices. However, the negative externalities of transgenic soybean production go far beyond the pollution arising from the use of glyphosate. Hence, the problem of "overplanting" transgenic soybean is a problem of regulating the output mix. Not only would regulating output quantities directly regulate the use of glyphosate, it would also promote a socially effi cient production structure by correcting the current reallocation of resources to transgenic soybean production.

Three alternative policy instruments are theoretically equivalent in achieving the desired reduction in transgenic soybean production: a "green" tax on transgenic soybean as a socially and environmentally harmful product, a subsidy for the production of non-transgenic soybean, and tradable production quotas. Two factors limit the relevance of a green tax in the Argentinian context. First, soybean producers already face a high export tax (35%) that reduces the price they receive compared to the corresponding export price. In March 2008, the government tried to raise the level of this tax up to 44%, but the tax pressure was felt to be intolerable and punitive by producers. This resulted in a serious conflict in which the producers started to protest and block roads. In the end, the government was forced to back down. Second, it is likely that the supply elasticity of transgenic soybean production to export tax is very low in Argentina. The export tax was heavily increased from 3.5% in 1992 to 35% in 2007, and has remained at this level since. In the meantime, production was multiplied by five, triggered by the dramatic increase in international prices. In such a context, a "green" tax will not be efficient in reducing the output. Hence, only the other two policy instruments will be discussed in this paper

This paper is the first attempt to propose a policy for regulating transgenic soybean in Argentina. Two policy instruments are considered. We first investigate the potential of subsidizing non-transgenic soybean. Second, we explore the implementation of transferable production quotas. We discuss the extent to which these instruments are efficient and cost-effective. In addition, two important constraints in designing the environmental policy will be considered: the first is the political acceptability associated with policy intervention; the second comes from the fact that fiscal revenue must be preserved in order to meet the debt service payment and other social expenses. We will therefore discuss the probability of acceptance of each policy instrument as well as the potential impact on the government budget.

The remainder of the paper is organized as follows. Section 2 gives an overview of transgenic soybean production in Argentina and its negative externalities. In Section 3 we introduce a framework describing the laissez-faire situation and defining the first-best regulation. Section 4 investigates the implementation of a subsidy for non-transgenic soybean. Section 5 explores the potential of transferable production quotas for transgenic soybean. Different initial allocation rules are discussed, as well as the probability of a "raising rivals' costs" strategy arising in the quota market. Our framework is extended to take into account the existence of a distortionary taxation in the economy in Section 6. Section 7 presents our concluding remarks.

2 The rapid expansion of transgenic soybean in Argentina and its negative externalities

Transgenic soybean seeds were introduced into Argentina in 1996 with glyphosate herbicide as an integral component of the production technique. The following decades witnessed a rapid expansion of planted area and production as well as deep technical and organizational changes. No-tillage sowing, massive applications of chemical inputs, and intensive mechanization of agricultural operations constitute the transgenic technological package that has been largely adopted. The introduction of transgenic cultivars for soybean has also gone hand in hand with the emergence and development of a new organization of production characterized by multiple contractual relationships. New associations of farmers, commonly named "sowing pools", were formed in order to extend the scale of production and collect enough capital to finance large production projects.

The dramatic success of this new model of production, commonly called the "modelo sojero" (the "soy model"), has been driven by many factors. First, the weak protection provided by intellectual property law constituted a strong institutional factor facilitating the expansion of transgenic soybean (Sztulwark & Braude, 2010; Pellegrini, 2013; Filomeno, 2013). The Argentinian law on seeds and phylogenetic creations promulgated in 1973 gives little protection to intellectual property rights because it recognizes the right of the producers to replant their own cultivars. Consequently, neither transgenic soybean seeds nor glyphosate have been protected by patents in Argentina. Moreover, a parallel market of transgenic soybean seeds gradually developed. As a result, Argentinian producers have acquired transgenic soybean at an abnormally low price, lower than that practiced by the large seed companies.

Second, transgenic soybean is less expensive to produce than non-transgenic soybean: many authors indicate a total saving of 20 dollars per hectare (Craviotti and Gras, 2006; Qaim and Traxler, 2005; Trigo and Cap, 2004). These savings arise from a better cultivation process which results in higher yields, reduced pest control costs, and big reductions in labor costs due to the mechanization of farming operations. Cultivating transgenic soybean has thus become the most profitable choice for farmers, much more so than non-transgenic soybean.

Third, public perception of the environmental impact of transgenic soybean in Argentina has long been low. Environmental policy lay outside the concerns of most Argentinian consumers, whose purchasing power had been seriously impacted by the policies implemented in the 1990s and by the financial crisis of 1998/2000. Also, transgenic soybean grains and by-products are almost entirely exported, so health hazards and safety issues are more likely to affect foreign consumers. Finally, a vast campaign of promotion of biotechnologies on behalf of the scientists, multinational farms, and some producers' associations whose members identified themselves as innovators contributed to promote this crop. A new social and economic cartography thus emerged around the oilseed complex, setting up alliances between actors belonging to various sectors of the economy (Gras and Hernandez, 2009). This resulted in a weak political demand for environmental regulation and transgenic soybean expansion did not face significant opposition.

Fourth, the Argentine rural sector, although socioeconomically fragmented, is well organized through four key agro-associations: the Argentine Rural Society (SRA), the Argentine Agrarian Federacion (FAA), the Confederation of Argentine Rural Societes (CRA) and the Intercooperative Association (ConInAgro), which represent different segments of the economic and political spectrum. The oldest and most powerful association is undoubtedly the SRA. Established in 1866, the SRA has always had close ties with the political sphere. In fact, many of its members traditionally held high-ranking positions in successive governments (Manzetti, 1992; Gras, 2012). Members of the SRA are part of the rural wealthy elite who own the largest landholdings and who played a leading role in the expansion of transgenic soybean cultivation. In contrast, small farmers make up the majority of the FAA's and CRA's membership which has the widest social base. Both associations usually battle to protect the interests of small/medium producers, regularly through the use of strikes. The coalition of these four key interest groups against any form of regulation is not unlikely. They have proved their rallying capacity in the past in reaction to the government's proposal to increase taxes on grain and oilseeds in 2008.

For its part, the government has shown little interest in fighting against the powerful agrarian lobby groups for two main reasons. First, there is a traditional class alliance in Argentina between the landed elites and the political powers, as mentioned above. Second, farming is the motor of the nation's economy and soybean is the country's most important export commodity, making a positive contribution to the Argentinian trade balance and providing a high share of the government's revenue (15-20%). This explains why, until recently, there has been little recognition of the deleterious environmental and social impact of the intensive mode of transgenic soybean production.

Nevertheless, transgenic soybean cultivation generates a wide range of negative environmental and social externalities. The most alarming impact of transgenic soybean cultivation arises from the intense use of glyphosate, which ensures the chemical control of weed infestation. Its consumption increased dramatically from 13.9 million liters in 1996 to 246 million liters in 2012 (CASAFE, 2012), and it could reach more than 300 million liters for the campaign 2015/2016, according to estimates. This massive and often unjustified increase in the use of glyphosate has been triggered not only by the expansion of the area cultivated in transgenic soybean but also by increased application frequencies resulting from pest resistance. Currently, there are more than twenty listed adventitious species which present a resistance to the weed killers available on the market (Vial-Aiub, 2008).

Although there is still debate over the toxicity of glyphosate, negative externalities arising from its use are now well documented in Argentina. They include soil contamination, air and water pollution, and health problems resulting from exposure to aerial spraying which affect not only farmers but also those living near farms (Arancibia, 2013; Carreño et al., 2012; de la Fuente et al., 2006; Gavier-Pizarro et al., 2012). In the treated zones, the rivers are contaminated and the flora and aquatic fauna have been destroyed (Casabé et al., 2007; Perez and al, 2007). In March 2015, the International Agency for Research on Cancer classified glyphosate in the A2 category, thus corroborating the observation of an increase in diseases (cancers, congenital birth defects, allergies, respiratory illnesses, etc.) in the rural population living in villages where aerial spraying of glyphosate is extensive (IARC, 2015; Gallegos et al., 2016; Schinasi and Leon, 2014).

The extension of soybean cultivation into more sensitive areas has also raised many other ecological problems. Intense deforestation in regions such as El Monte, destruction of ecosystems, loss of species richness particularly in sensitive bio-diverse ecoregions such as the Yungas or the Great Chaco (Gavier-Pizarro et al., 2012), are threatening the habitations of indigenous people and small farmers. Rising violence linked to land-grabbing has also been noted.

Another aspect of the "modelo sojero" that has been very hotly debated in

Argentina is the typical network-based system of transgenic soybean production. This organization of production has triggered a strong trend of separation between landowning and land cultivation, a significant growth in the number of short-term land leasing agreements, and the increasing importance of sowing pools as renters. It is argued that the increase in tenancy has given strong incentives for the intensification of land use and the rapid change from rotational cropping patterns to permanent soybean production. Many studies highlight the detrimental impact that the abandonment of crop rotation has on yields (Caviglia and Andrade, 2010; Rótolo et al., 2015), whereas others emphasize the negative implications of indirect land tenure on fertilization, the adoption of conservation practices, and long-term land improvements (Abdulai et al., 2011; Myyrä et al., 2007; Soule et al., 2000).

Finally, the expansion of transgenic soybean has undoubtedly reduced the labor absorption in agriculture. The technological leap introduced by biotechnologies associated with intense mechanization of the production process has destroyed many jobs at the farm level (Phélinas and Choumert, 2017). An increase in unemployment and the persistence of a high incidence of poverty in the villages and rural towns of transgenic soybean production zones have recently been highlighted (Caceres, 2015).

3 The model

In this section we first describe the "laissez-faire" context, when the farmers' decision whether to grow transgenic or conventional soybean is not constrained by policy regulation. We then define the first-best regulation.

3.1 The "laissez-faire" context

Consider a representative farm producing a quantity y_1 of transgenic soybean at a cost $C_1(y_1)$ and/or non-transgenic soybean y_2 at a cost $C_2(y_2)$ with $C_1(y_1) < C_2(y_2)$.[1] Both cost functions are increasing and convex.[2] Available land is limited to T.[3] The production of y_1 (y_2) needs a surface y_1 (y_2) such that: $T \geqslant y_1 + y_2$.[4]

All the farms are assumed to be price-takers. The soybean price (denoted P) is set competitively on an international market. We assume that the market determines a single price for transgenic and non-transgenic soybean.[5] In this

[1] As already noted, neither transgenic soybean seeds nor glyphosate are protected by patent in Argentina, drastically reducing their cost.

[2] We also assume $C_1'''(y_1) < 0$. This condition always ensures the concavity of the profit function when we consider regulation with an imperfect competitive quota market.

[3] We assume that in our short-term analysis, it is not possible to further extend agricultural land.

[4] In a first step of transgenic soybean regulation in Argentina, we assume that it is less expensive to return to non-transgenic soybean than to substitute it by other crops.

[5] Even if the international market sets a price premium for non-transgenic soybean, the non-transgenic soybean producers do not receive it (Fok and al., 2010).

context, the representative farm chooses the optimal level of transgenic and non-transgenic soybean production that maximizes its profit:

$$\Pi(y_1, y_2) = P.(y_1 + y_2) - C_1(y_1) - C_2(y_2) - \lambda(y_1 + y_2 - T)$$

$$P - C_1'(y_1^d) - \lambda^d = 0 \tag{1}$$

$$P - C_2'(y_2^d) - \lambda^d = 0 \tag{2}$$

$$\lambda^d[y_1^d + y_2^d - T] \leqslant 0 \tag{3}$$

Solving (1) and (2) yields:

$$C_1'(y_1^d) = C_2'(y_2^d) \tag{4}$$

The capacity constraint is assumed to be bounded, i.e., $\lambda^d > 0$.[6] It follows from (3) that the global production of soybean equals T. Each producer chooses an optimal level of transgenic and non-transgenic production such that marginal costs of production are equal. As $C_1'(y_1^d) = [C_2'(T - y_1^d)]$, $y_1^d > y_2^d$ with $y_1^d > T/2$ (because $C_1'(y_1) < C_2'(y_2)$), it follows that if the cost of producing non-transgenic soybean is much higher than that of transgenic soybean, the level of production will be very low. The expansion of transgenic soybean observed in Argentina, triggered by its low cost of production, is a salient illustration of these theoretical predictions.

3.2 The first-best

Assuming that there is a functional relationship between the level of transgenic soybean production and its externalities, let $D(y_1)$ be the total damage caused by transgenic soybean production, with $D'(y_1) > 0$ and $D''(y_1) > 0$. In order to set the first-best, i.e., the optimal level of transgenic soybean production, the social planner maximizes a welfare function taking into account the representative farm's profit but also the environmental damage induced by the production of transgenic soybean.[7] This function can be written as follows:

$$W(y_1, y_2) = P.(y_1 + y_2) - C_1(y_1) - C_2(y_2) - \lambda(y_1 + y_2 - T) - D(y_1)$$

$$P - C_1'(y_1^{**}) - \lambda^{**} - D'(y_1^{**}) = 0 \tag{5}$$

$$P - C_2'(y_2^{**}) - \lambda^{**} = 0 \tag{6}$$

$$\lambda^{**}[y_1^{**} + y_2^{**} - T] \leqslant 0 \tag{7}$$

From (5) and (6), each level of production satisfies:

$$C_1'(y_1^{**}) + D'(y_1^{**}) = C_2'(y_2^{**}) \tag{8}$$

[6] This assumption is realistic because in Argentina the expansion of genetically modified soybean production has occurred mainly through the expansion of the land frontier to marginal areas. Hence, nowadays almost all the land suitable for soybean cultivation is in use.

[7] As soybean production is mainly exported, the domestic consumer surplus is not taken into account in the welfare function.

Assuming that the constraint on available land is bounded, it follows that $\lambda^{**} > 0$ and $y_1^{**} + y_2^{**} = T$. As a result, the profitability of soybean production is reduced ($\lambda^{**} < \lambda^d$). Comparing Eq. (4) and (8) shows that taking into account the damage leads to a reduction in transgenic soybean production and an increase in non-transgenic soybean production: $y_1^{**} < y_1^d$ and $y_2^{**} > y_2^d$. If the damage is very high, it is even possible for the social planner to choose a higher level of production for non-transgenic soybean than transgenic soybean.

4 Subsidy of non-transgenic soybean

We first discuss the implementation of a subsidy on non-transgenic soybean to decentralize the first-best production level of transgenic soybean. If the regulator sets a subsidy S per unit of non-transgenic soybean, the profit of the representative farm can be written as follows:

$$\Pi(y_1, y_2, \lambda) = P.(y_1 + y_2) - C_1(y_1) - C_2(y_2) + S.y_2 - \lambda(y_1 + y_2 - T)$$

$$P - C_1'(y_1^s) - \lambda^s = 0 \tag{9}$$

$$P - C_2'(y_2^s) - \lambda^s + S = 0 \tag{10}$$

$$\lambda^s[y_1^s + y_2^s - T] \leqslant 0$$

From (9) and (10), the solution fulfills:

$$C_1'(y_1^s) + S = C_2'(y_2^s) \tag{11}$$

If $S = D'(y_1^s)$, then Eq. (11) is identical to Eq. (8) when $\lambda^s > 0$. Thus, a well-designed subsidy for non-transgenic soybean is an effi cient instrument which makes it possible to reach the first-best outcome.

However, this instrument is costly for public finances. It is thus unlikely to be implemented in Argentina, because of the explosive debt accumulation that led to debt service payments reaching 4.7% of GDP in 2016 (Cibils, 2011). The fiscal effort to meet these payments is expected to require higher tax revenues and/or spending cuts. In this context, the subsidizing of non-transgenic soybean would compete with other fiscal resources devoted to programs that transfer wealth to the poor, which could raise a problem of public acceptability.

The payment of this subsidy could be transferred to the private market. Indeed, there is an international market price premium for non-transgenic soybean. A good substitute for the payment of this subsidy would be to make sure that the non-transgenic soybean producers receive this market premium. That would achieve the first-best without supplementary costs for the taxpayers. However, in the current state of things, non-transgenic soybean producers do not capture this premium, mainly because conventional soybean is not marketed as part of a chain with certi cation (Fok and al., 2010). The Cartagena

Protocol on Biosafety requires that the quality attributes of non-transgenic soybean should be preserved throughout the whole supply chain, from producers to end consumers. This involves generating a system of traceability and labeling to distinguish between transgenic and non-transgenic soybean throughout the whole supply chain. This process could be very costly to implement since it requires a system of separation at every stage of the supply chain: field isolation to avoid contamination; cleaning of facilities used for handling, processing and transport; testing for product purity, etc. Without international rules to organize supply chains for both transgenic and non-transgenic soybean, it is unlikely that transgenic soybean production will be challenged by the market price premium on conventional soybean.

5 Tradable production quotas

Let us now consider that the regulating authority issues a given amount of tradable production quotas in order to control the level of transgenic soybean production. We relax the assumption of a representative farm and consider N identical farms. For simplicity, each quota gives the right to produce one unit of transgenic soybean. To hold a quota is a legal constraint enforced by law.[8] Confronted with this new regulation, each agricultural farm has to hold an amount (q_i) of production quotas corresponding to its desired level of production such that $q_i = y_{1i}$. Production quotas are freely issued or sold to farms in a primary market. Section 5.1 investigates the case where quotas are traded on a secondary market at a competitive price P_q whereas Section 5.2 introduces market power on the quota market.

5.1 A competitive quota market

Since a major issue in setting production quotas is the way they are allocated, various options are discussed. In brief, these are (a) a free lump-sum allocation; (b) an auction; and (c) an output-based allocation. In the following, we assess the extent to which different initial quota allocations achieve the first-best. The distributional effects of each quota allocation and, accordingly, its political acceptability, are examined as well.

5.1.1 A free lump-sum allocation

In a free lump-sum allocation, the regulator allocates Q production quotas freely to farms such that:

$$\bar{Q} = y_1^{**}. \tag{12}$$

Quotas are distributed following an appropriate criterion, be it a benchmark of past production levels ("grandfathering"), other past criteria, or the political influence of interest groups. Farms are allowed to trade quotas in a secondary

[8] We assume the penalty is suffi ciently high to induce agricultural farms to comply with this policy.

market. Each farm receives $\bar{q}_i$ such that $\bar{Q} = \sum_{i=1}^{N} \bar{q}_i$. Integrating this new constraint into the cropping decision, Farm i chooses to produce respectively y_{1i} (y_{2i}) amounts of transgenic (non-transgenic) soybean. The new profit function is:

$$\Pi_i(y_{1i}, y_{2i}, \lambda) = P.(y_{1i}+y_{2i}) - C_1(y_{1i}) - C_2(y_{2i}) - P_q(y_{1i} - \bar{q}_i) - \lambda(\sum_{i=1}^{N} y_{1i} + \sum_{i=1}^{N} y_{2i} - T)$$

$$P - C_1'(y_{1i}^{ls}) - \lambda^{ls} - P_q^{ls} = 0,\ i = 1, ..., N \tag{13}$$

$$P - C_2'(y_{2i}^{ls}) - \lambda^{ls} = 0,\ i = 1, ..., N \tag{14}$$

$$\lambda^{ls}[\sum_{i=1}^{N} y_{1i}^{ls} + \sum_{i=1}^{N} y_{2i}^{ls} - T] \leqslant 0 \tag{15}$$

Solving (13) and (14) yields:

$$C_1'(y_{1i}^{ls}) + P_q^{ls} = C_2'(y_{2i}^{ls}) \tag{16}$$

As farms can trade their quotas, farm i will buy (sell) quotas if the desired level of production exceeds (is inferior to) the allowance received, i.e., if $[y_{1i}^{ls} - \bar{q}_i] > 0$ (< 0). These exchanges on the secondary market set the price of the production quota P_q^{ls} such that: $\bar{Q} = \sum_{i=1}^{N} y_{1i}^{ls}$. As the total amount of production quotas is $\bar{Q} = y_1^{**}$, we necessarily have $P_q^{ls} = D'(\sum_{i=1}^{N} y_{1i}^{**})$. Therefore, the competitive price of quotas creates appropriate incentives for farms to choose the "good" level of transgenic and non-transgenic soybean production such that $\sum_{i=1}^{N} y_{1i}^{ls} = y_1^{**}$ and $\sum_{i=1}^{N} y_{2i}^{ls} = y_2^{**}$.[9] If the first-best level of transgenic soybean is reached through the setting of the global quantity of production quotas, cost-efficiency is promoted by the trade in quotas.

Applying the Implicit Function Theorem on Equation (16) shows that the level of production of transgenic (non-transgenic) soybean decreases (increases) with the price of the production quotas. So the introduction of production quotas for transgenic soybean changes the relative share of transgenic versus conventional soybean in total production, while there is no direct regulation of the latter.

In Equations (13) and (14), the initial distribution of production quotas does not appear. This means that whatever the quantity of quotas any producer initially receives, the final distribution of transgenic soybean production does not change. This is because when quotas are grandfathered, the initial allocation of quotas is equivalent to a lump sum subsidy independent of production levels. This result is consistent with Montgomery (1972).

[9] As $y_2^{ls} = T - y_1^{**}$, we necessarily have $y_2^{ls} = y_2^{**}$.

A free lump-sum allocation is a very appealing instrument for the regulator because it offers a great choice of allocation criteria facilitating the control over the distributional effects of regulation and therefore political acceptance without changing cost-efficiency. The regulator may allocate more quotas to farms which already produce non-transgenic soybean, or allocate everything to them and nothing to the others. He may also give equal shares to all transgenic soybean producers or quotas in proportion to their past production (or land cultivated).

In Argentina, a distributional design based on historical output appears a possible option, because it would favor existing producers and convey rents to the largest ones. As a result, this allocation rule might elicit support for the regulation from the largest producers, since it would satisfy the demands of the SRA's influential members. However, quota distribution based on past output might be considered unfair by many small or medium producers who would have difficulty in maintaining or increasing their market share. Giving the inherent rent-seeking nature of the Argentinian agricultural organizations, this allocation rule might provoke a long-lasting fight between interest groups to capture a greater share of the allocation or to seek exemptions. This might in turn result in large amounts of time lost to lobbying and delays in implementation.

Finally, a free lump-sum allocation has another important shortcoming. The initial allocation of quotas may result in an imperfect quota market, depending on the relative bargaining power of producers. In Section 5.2, we show that an imperfect quota market leads to an inefficient outcome, as Hahn (1984) demonstrated for tradable pollution rights in his seminal paper.

5.1.2 An auction

Instead of freely allocating the production quotas, the social planner could auction them. This alternative is an interesting one in Argentina where agriculture has long been an essential source of fiscal revenue. When quotas are auctioned, the regulator raises revenue by issuing $\bar{Q} = y_1^{**}$ production quotas. In this case, the initial quota distribution is null ($\bar{q}_i = 0$, $\forall i$), so each farm has to buy the right to produce transgenic soybean. The farms' profit is similar to that with free lump-sum allocation, setting $\bar{q}_i = 0$. As the conditions of Equation (16) under free lump-sum allocation are satisfied, auctioning quotas achieves the first-best while raising revenue.

The main political economic disadvantage is that auctioned quotas might face stronger political opposition than grandfathering. In Argentina, there are good reasons to fear fierce resistance from interest groups forming the very powerful associations already mentioned, more concerned with protecting the income of their members than with social and environmental considerations.

One way to reconcile divergent public and private interests would be to use the income from auctioned quotas to cut the very unpopular taxes on soybean exports and/or to compensate for the fall in farms' profit resulting from the regulation. Moreover, equity can be achieved through the use of the revenue resulting from auction quotas. This revenue could also be used to compensate for the negative externalities of transgenic soybean cultivation such as health damage induced by glyphosate, to provide assistance for laid-off workers to change industries, to finance additional public goods or simply to correct fiscal imbalances. In all cases, revenue must be issued in the form of lump-sum transfers in order to avoid strategic behavior.

5.1.3 Free output-based allocation

The regulator might decide to allocate a share of quotas $\bar{Q} = y_1^{**}$ to Farm i according to its current production level. In this case, a farm producing y_{1i} will receive $f(y_{1i})$ quotas with $f'(y_{1i}) > 0$. Other farms receive a global quantity $\bar{Q} - f(y_{1i})$ of quotas distributed according to a free lump-sum allocation. The farm i solves the following problem:

$$\Pi_i(y_{1i}, y_{2i}, \lambda) = P.(y_{1i}+y_{2i})-C_1(y_{1i})-C_2(y_{2i})-P_q(y_{1i}-f(y_{1i}))-\lambda(\sum_{i=1}^{N} y_{1i}+\sum_{i=1}^{N} y_{2i}-T)$$

$$P - C_1'(y_{1i}^{ob}) - P_q + P_q.f'(y_{1i}^{ob}) - \lambda^{ob} = 0,\ i = 1, ..., N \tag{17}$$

$$P - C_2'(y_{2i}^{ob}) - \lambda^{ob} = 0,\ i = 1, ..., N \tag{18}$$

$$\lambda^{ob}[\sum_{i=1}^{N} y_{1i}^{ob} + \sum_{i=1}^{N} y_{2i}^{ob} - T] \leqslant 0 \tag{19}$$

Solving (17) and (18) yields:

$$C_1'(y_{1i}^{ob}) + P_q^{ob} - P_q.f'(y_{1i}^{ob}) = C_2'(y_{2i}^{ob}) \tag{20}$$

We show that if production quotas are issued according to an output-based allocation, the distribution is endogenous for Farm i. As $f'(y_{1i}) > 0$, according to Equations (20) and (16), $y_{1i}^{ob} > y_{1i}^{ls}$. Producing one unit of transgenic soybean costs P_q to buy a production quota but generates a gain corresponding to $P_q.f'(y_{1i})$. Hence, this allocation rule gives an additional incentive to this producer to cultivate more transgenic soybean. As a result, the output-based distribution does not imply cost-effi ciency.

5.2 An imperfectly competitive quota market

In the previous section, we assumed that production quotas were tradeable on a competitive secondary market. This assumption leads to a cost-effective solution when the initial quota allocation is grandfathered or auctioned. However, farms face diminishing returns resulting from the regulation. As the soybean price is internationally set, farms cannot influence market price on their own, but they may try to restore their profit by exercising market power on the production quota market. A "predatory farm" could induce rivals to exit the market by raising their costs. This is known as a non-price predatory behavior (Salop and

Scheffman, 1983). As farms need production quotas to produce, quotas can be used as exclusionary rights. According to Krattenmaker and Salop (1986-1987), a "predatory purchaser" could buy a large portion of the quota supply, withholding that portion from rivals, thereby driving up the market price of the quotas available to rivals. This "supply squeeze" or "quantitative foreclosure" is the result of unfair competition in the quota market.

The probability that some farms may try to manipulate the quota price in order to reduce their conformity cost is high in Argentina. According to Marin and Perez (2011), although the primary production comprises a large number of producers (around 73 thousand), only 6% of producers account for 54% of the production. This small group, representative of large-scale agriculture (pools of sowing), was consolidated as a new actor in the last two decades. It is not unlikely that these very powerful producers and/or associations of producers may collude and adopt a dominant position in the production quotas in order to keep their advantage in the production market.

In this section, we investigate whether a dominant farm on the production quota market will just use its market power to minimize its cost of compliance to soybean regulation or whether it will try to raise rivals' costs. To explore this idea, we assume two representative farms or groups of farms. Farm 1 (for example, a "sowing pool") will adopt a non-competitive behavior on the secondary market whereas Farm 2 (the competitive fringe) will act as a price-taker. In such a context, the dominant farm first sets the price of the production quotas. Then, each farm chooses its optimal level of production taking both soybean and quota prices as given. This problem must be solved using backward induction (Sartzetakis, 1994 and 1997).

5.2.1 The second step

In this step, each farm chooses its level of production taking both prices (P_q and P) as given. As production decisions must be consistent with the quota market equilibrium, the dominant farm has to take into account this constraint in its profit. Let γ be the associated Lagrangian multiplier. The dominant farm maximizes the following program:

$$\begin{aligned}\Pi_1(y_{11}, y_{21}, \lambda, \gamma) \quad = \quad & P(y_{11} + y_{21}) - C_1(y_{11}) - C_2(y_{21}) - P_q(y_{11} - \bar{q}_1) \\ & -\lambda(y_{11} + y_{21} + y_{12} + y_{22} - T) - \gamma(y_{11} + y_{12} - \bar{Q})\end{aligned}$$

$$P - C_1'(y_{11}^{rc}) - P_q^{rc} - \lambda^{rc} - \gamma^{rc} = 0 \tag{21}$$

$$P - C_2'(y_{21}^{rc}) - \lambda^{rc} = 0 \tag{22}$$

$$y_{11}^{rc} + y_{21}^{rc} + y_{12}^{rc} + y_{22}^{rc} - T = 0 \tag{23}$$

$$y_{11}^{rc} + y_{12}^{rc} - \bar{Q} = 0 \tag{24}$$

The levels of production for Farm 2 (y_{21} and y_{22}) are given by Eqs. (13) and (14). Solving the system of Equations (21), (22), (23), (24), (13) and (14) (see Appendix) yields: $y_{21}^{rc} = y_{22}^{rc} = f(T, \bar{Q})$, $y_{11}^{rc} = f(Pq, \bar{Q}, T)$, $y_{12}^{rc} = f(Pq, \bar{Q}, T)$, $\lambda^{rc} = f(P, T, \bar{Q})$ and $\gamma^{rc} = f(Pq, \bar{Q}, T)$, with $\frac{\partial y_{11}^{rc}}{\partial Pq} > 0$ and $\frac{\partial y_{12}^{rc}}{\partial Pq} < 0$. It remains to find the value of Pq^{rc}. As the level of production of the dominant farm increases with the production quota price, we expect this farm to try to increase this price in order to expand its production level.

5.2.2 The first step

In the first step, the dominant farm sets the price of the production quotas. Replacing the values obtained above in the profit function, we can write the new profit function as:

$$\Pi_1(Pq, \bar{Q}, \bar{q}_1, P, T)$$

From Appendix, the quota price is such that the following equality holds:

$$y_{1i}^{rc}(Pq, \bar{Q}, \bar{q}_1) - \bar{q}_1 = \frac{\partial y_{11}^{rc}(Pq, \bar{Q}, \bar{q}_1)}{\partial Pq}(P - C_1'(y_{11}^{rc}(Pq, \bar{Q}, \bar{q}_1)) - P_q) \tag{25}$$

Eq. (25) shows that the optimal quota price is such that the net demand of quotas of the dominant farm equals the change in its marginal profit. Solving Equation (25), we obtain the manipulated quota price:

$$Pq^{rc} = f(\bar{Q}, \bar{q}_1, P, T) \text{ with } \frac{\partial Pq^{rc}}{\partial \bar{q}_1} > 0 \tag{26}$$

Two kinds of market manipulation are distinguished in the economic literature (Misiolek and Elder, 1989). If the dominant farm just uses its market power on the quota market to reduce its compliance cost, it practices simple manipulation. But if this farm seeks to obtain an advantage by manipulating the quota price, it practices exclusionary manipulation. Equation (25) shows that the manipulated price takes into account not only the production quota market but also the output market. Thus the dominant farm does not just use its market power on the production quotas in order to minimize its compliance cost. It also tries to raise the quota price in order to increase rivals'costs, acting as a predatory farm.

As $\bar{q}_1$ is present in Eq. (26), the initial distribution matters in the setting of the quota price. This means that the final distribution of production quotas is no longer independent of the initial allocation.[10] Thus, the result obtained under the assumption of a competitive market of production quotas in Section 5.1.1 is challenged. Imperfect competition on the quota market involves a positive correlation between the initial distribution and the level of the manipulated quota price.

In that case, the regulator can use the initial distribution to restore the first-best outcome. Let us assume that the regulator sets an initial distribution such

[10] See Hahn (1984) and Sartzetakis (1994) and (1998) for a study of tradable pollution permit markets.

that the dominant farm has no incentive to interfere on the production quota market, i.e., $\bar{q}'_1 = y^{rc}_{11}(Pq, \bar{Q}, T)$. The regulator grants the dominant farm a quota amount corresponding to its gain when it manipulates the quota market. From (25), it follows $P - C'_1 - P_q = 0$. But according to (13), $P - C'_1 - \lambda - P_q = 0$ induces cost-efficiency. Therefore the regulator cannot restore the first-best with the initial allocation $\bar{q}'_1$. He would do better choosing another allocation $\hat{q}_1$, such that:

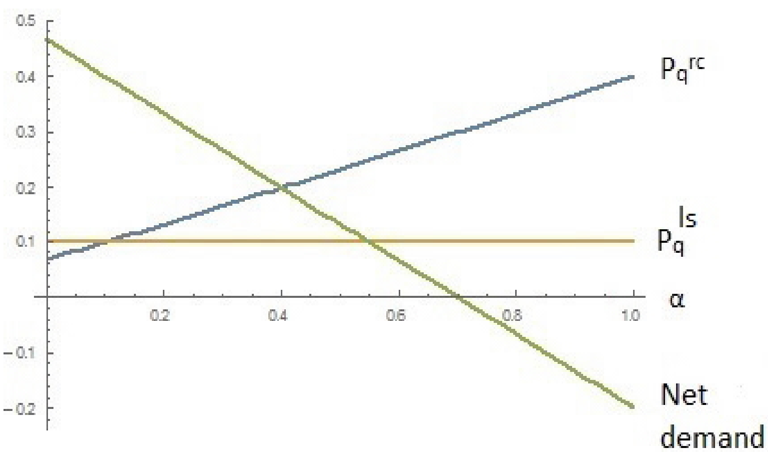
$$\hat{q}_1 / . P_q^{rc}(\bar{q}_1) = P_q^{ls}$$

Without this key initial distribution, the production quota market does not implement cost-efficiency. However, in this latter case, efficiency is restored but at the expense of equity.

According to Salop and Scheffman (1987), the strategy of raising rivals' costs aims to increase the output price. This is always the case in studies about tradable pollution permits (Misiolek and Elder, 1989, Sartzetakis, 1994, 1997, Eschel, 2005). In our analysis, we show that this strategy can be pursued even when the output price cannot be changed because it is set on an international market. Production quotas are specific inputs without which production is impossible. Overbuying quotas is sufficient to exclude competitors, and the consecutive increase in the quota price just reinforces exclusion. The benefit of this strategy for the predatory farm comes from manipulation of the quota market and from increased production. As $\frac{\partial P {q}^{rc}}{\partial \bar{q}_1} > 0$, one way to limit this behavior is to auction quotas.

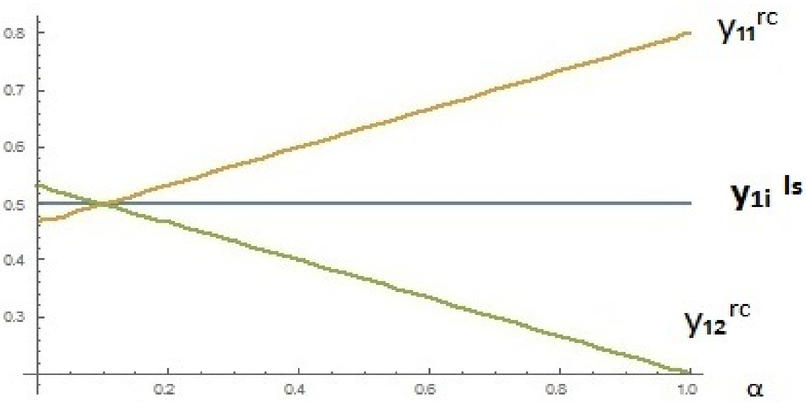
In order to better understand the effects of the dominant farm's strategy, we use a numerical example. We set $P = 1$, $\bar{Q} = 1$, $T = 1.6$, $C_1(y_{1i}) = \frac{y_{1i}^2}{2}$, $C_2(y_{2i}) = y_{2i}^2$ and $\bar{q}_1 = \alpha\bar{Q}$ with $\alpha \in [0; 1]$. Results are summarized in Figures 1 and 2.

2



$_1.jpg$

Price variations and net demand of the dominant firm manip



2.jpg

Transgenic soybean production levels under perfectly and imperfectly competitive quota market

The manipulated quota price, the competitive quota price and the net demand of the dominant farm given by $[y_{1i}^{rc} - \bar{q}_1]$ are represented in Figure 1 according to the initial allocation, denoted (α). Transgenic soybean production levels under competitive and non-competitive quota markets according to α are given in Figure 2. From these figures we can see that the dominant farm strategy leads to an increase in the quota price and in its production level at the expense of the competitive fringe. If the regulator gives the dominant farm a higher share of the initial quota, he will push up the quota price as well as the dominant farm production level. If $\alpha = 0.7$ (corresponding to $\bar{q}_1'$), the dominant farm does not intervene on the quota market but the quota price is higher than it would be on a competitive market. From both Figure 1 and Figure 2 we observe that if the dominant farm receives an initial allocation such as $\alpha = 0.1$ (i.e., corresponding to $\hat{q}_1$), the equilibrium transgenic soybean production is the same whether the quota market is imperfectly or perfectly competitive.

The net demand of the predatory farm is positive if $\alpha < 0.7$ and negative if $\alpha > 0.7$. We observe that the quota price is always higher than its competitive level if the predatory farm acts as a seller on the quota market. When it acts as a buyer, the quota price is lower than its competitive level if $\alpha < 0.1$ but *higher* if $0.1 < \alpha < 0.7$. The aim of simple manipulation is to reduce (increase) the quota price when the dominant farm is a buyer (seller), whereas the aim of exclusionary manipulation is always to increase it. If the dominant farm exerts monopoly power in the quota market, both manipulations lead to an increase in the quota price. If the dominant farm exerts monopsony power, the aim of simple manipulation is to reduce the quota price, whereas the aim of exclusionary manipulation is to increase it. The resulting manipulated price depends on both effects. Finally, the quota price can be higher than its competitive level even though the farm acts initially as a monopsony in the quota market.

6 An extension: considering distortionary taxation

Using a Computable General Equilibrium, Chisari and Cicowiez (2010) found that the marginal cost of public funds ranges from 0.67 to 1.50 in Argentina, depending on the type of tax levied to increase the revenue of the government and on the type of price regulation.[11] Let us denote β the marginal cost of public funds. When the regulator raises taxes \$1, the cost to society is $\$(1+\beta)$. Accordingly, the revenue issued from auctioned quotas must be computed at the shadow cost of public funds $(1+\beta)$, because it reduces the need for distortionary taxation in other sectors of the economy. Under this new assumption and considering a representative agricultural farm, the regulator sets a new optimal level of production quotas that maximizes the following welfare function:

$$W(y_1, y_2, \lambda) = P.(y_1 + y_2) - C_1(y_1) - C_2(y_2) + \beta P_q y_1 - \lambda(y_1 + y_2 - T) - D(y_1)$$

$$P - C_1'(y_1^{dt}) - \lambda^{dt} - D'(y_1^{dt}) + \beta P_q^{dt} = 0 \tag{27}$$

$$P - C_2'(y_2^{dt}) - \lambda^{dt} = 0 \tag{28}$$

$$\lambda^{dt}[y_1^{dt} + y_2^{dt} - T] \leqslant 0$$

Solving (27) and (28) yields:

$$C_1'(y_1^{dt}) + D'(y_1^{dt}) - \beta P_q^{dt} = C_2'(y_2^{dt}) \tag{29}$$

Comparing Equation (8) and Equation (29) shows that the introduction of a

distortionary taxation prevents the regulator from reaching the first-best. Taking into account the tax payers'welfare thus leads to allowing a higher level of transgenic soybean production. As such, distortionary taxation is detrimental to environment and society.

7 Conclusion

Transgenic soybean production has become one of the strategic components of Argentina' seconomy, and of the country's international positioning. However, transgenic soybean production has increased the dependence of the Argentine economy on soybean production and exports, raised social questions, and induced numerous negative externalities such as deforestation, soil pollution and

[11] The marginal cost of public funds measures the loss incurred by society in raising additional revenues to finance government spending. See, among others, Dahlby (2008) for a detailed analysis.

health problems resulting from the intensive use of glyphosate. Considering the environmental, health and social costs arising from transgenic soybean expansion, policy action is needed to promote a socially optimal output mixture.

This paper is the first attempt to propose a policy for regulating transgenic soybean in Argentina. The proposed regulation is based on output limitation instead of input application control. We begin by setting the optimal level of transgenic soybean production, and then successively examine two policy instruments, a subsidy on the production of non-transgenic soybean and tradable production quotas for transgenic soybean. We show that a well-designed subsidy decentralizes the first-best level of transgenic soybean production but is costly to implement. Since it would be diffi cult to raise funds to finance a subsidy in Argentina we explore another way to "subsidize" producers of non-transgenic soybean. This would consist in ensuring that they receive the non-transgenic soybean market premium. This is not currently the case because the supply chain does not separate transgenic and conventional soybean. Such a separation would require that the international community organize both distribution chains as specified by the Cartagena Protocol on Biosafety, which is not the case today. In addition, even if conventional soybean producers could receive this price premium, its level would have to be exactly equal to the level of the marginal damage induced by the transgenic soybean. This will occur only by chance in a real world.

We then investigated the potential of tradable production quotas to regulate transgenic soybean production. Production quotas give considerable flexibility to the controlling authority in the initial allocation rules, making it possible to control effi ciency, equity and political acceptability. We showed that whereas a free lump-sum allocation is likely to provide political acceptability, an auction should be preferred if equity is a concern, although it could provoke strong political opposition. Equity and political opposition could be reconciled in a well-designed debate about the way auction revenue would be spent. For example, the auction revenue could be used to compensate losses in farms'profits, to cut the very unpopular export taxes, or to compensate for the damage caused by the massive use of glyphosate.

One shortcoming of production quotas comes from the fact that the organization of the agricultural sector is such that a strategy of raising rivals'costs is likely to occur on the production quota market. We showed that this strategy is profitable for a predatory farm even if the output price is set exogenously. If predatory behavior occurs on the production quota market, the first-best level of transgenic soybean production is still achieved, but not cost-effi ciency. One way to limit this predatory strategy is to auction quotas.

Finally, we considered an extension of our framework. We assumed that there is distortionary taxation in the economy. We showed that in this case, a larger amount of production quotas will be sold than in the first-best. Hence, taking into account the tax payers'welfare is detrimental to the environment.

This article presents a first step in transgenic soybean regulation. We assume that it is less expensive to substitute traditional soybean for transgenic soybean than to adopt other crops. In this case, total soybean production, and consequently the export tax revenue, are unchanged. So, this proposal could be adopted by the Argentinian authorities. However, further research could extend our work by analyzing a second step in transgenic soybean regulation. Other agricultural productions could be increased at the expense of both transgenic and non-transgenic soybean production. Given that Argentina is the world's third largest producer of soybean and the leading exporter of soybean pellets, we will take into account the extent to which reducing Argentinian global soybean production would impact the world price of soybean.

8 Appendix

The "laissez-faire" From (1) and (2) we have: $y_1^d = (C_1')^{-1}(P-\lambda^d)$ and $y_2 = (C_2')^{-1}(P-\lambda^d)$. λ^d is such that $T-(C_1')^{-1}(P-\lambda^d)-(C_2')^{-1}(P-\lambda^d)=0$.

A free lump-sum allocation Assuming $N=2$, from Eq. (12), (13), (14) and (15), we find: $y_{11}^{ls} = y_{12}^{ls} = (C_1')^{-1}(P-P_q^{ls}-\lambda^{ls})$, $y_{21}^{ls} = y_{22}^{ls} = (C_2')^{-1}(P-\lambda^{ls})$, $\bar{Q} = y_{11}^{ls}+y_{12}^{ls}$ and $T = y_{11}^{ls}+y_{12}^{ls}+y_{21}^{ls}+y_{22}^{ls}$. Solving this system we obtain:

$$y_{11}^{ls} = \frac{\bar{Q}}{2} = y_{12}^{ls}$$

$$y_{21}^{ls} = \frac{T-\bar{Q}}{2} = y_{21}^{ls}$$

$$\lambda^{ls} = P - C_2'(\frac{T-\bar{Q}}{2})$$

$$P_q^{ls} = C_2'(\frac{T-\bar{Q}}{2}) - C_1'(\frac{\bar{Q}}{2})$$

From (16), we set $F(y_{1i}, y_{2i}, P_q) = C_1'(y_{1i}^{ls})+P_q^{ls}-C_2'(y_{2i}^{ls})$. Applying the Implicit Function Theorem, we find: $\frac{\partial y_{1i}^{ls}}{\partial P_q} = C_1''(y_{1i})^{-1} < 0$ and $\frac{\partial y_{2i}^{ls}}{\partial P_q} = C_2''(y_{2i})^{-1} > 0$, $\forall i$.

An imperfectly competitive quota market

(i) Determination of y_{11}^{rc}, y_{12}^{rc}, y_{21}^{rc}, y_{22}^{rc}, λ^{rc} and γ^{rc}

From Eqs. (13), (14), (21) and (22) we have: $y_{11}^{rc} = (C_1')^{-1}(P-P_q-\lambda^{rc}-\gamma^{rc})$, $y_{12}^{rc} = (C_1')^{-1}(P-P_q-\lambda^{rc})$, $y_{21}^{rc} = (C_2')^{-1}(P-\lambda^{rc})$ and $y_{22}^{rc} = (C_2')^{-1}(P-\lambda^{rc})$. From (23) and (24) and replacing y_{21}^{rc} and y_{22}^{rc}, we find:

$$\lambda^{rc} = P - C_2'(\frac{T-\bar{Q}}{2}) \tag{A1}$$

Replacing (A1) in (24), we obtain:

$$\gamma^{rc} = -P_q + C_2'(\frac{T-\bar{Q}}{2}) - C_1'(\bar{Q} - C_1'^{-1}(-P_q + C_2'(\frac{T-\bar{Q}}{2}))) \tag{A2}$$

Using (A1) and (A2), we find:

$$y_{11}^{rc} = \bar{Q} - (C_1')^{-1}(-P_q + C_2'(\frac{T-\bar{Q}}{2})) = f(Pq, \bar{Q}, T)$$

with $\frac{\partial y_{11}^{rc}}{\partial Pq} = 1/(C_1''(-P_q+C_2'(\frac{T-\bar{Q}}{2}))) > 0$ and $\frac{\partial^2 y_{11}^{rc}}{\partial Pq^2} = C_1'''(-P_q+C_2'(\frac{T-\bar{Q}}{2}))/[C_1''(-P_q+C_2'(\frac{T-\bar{Q}}{2}))]^2 < 0$.

$$y_{12}^{rc} = (C_1')^{-1}(-P_q + (C_2')^{-1}(\frac{T-\bar{Q}}{2}))) = f(Pq, \bar{Q}, T)$$

with $\frac{\partial y_{12}^{rc}}{\partial Pq} = -1/(C_1''(-P_q+C_2'(\frac{T-\bar{Q}}{2}))) < 0$ and $\frac{\partial^2 y_{12}^{rc}}{\partial Pq^2} = -C_1'''(-P_q+C_2'(\frac{T-\bar{Q}}{2}))/[C_1''(-P_q+C_2'(\frac{T-\bar{Q}}{2}))]^2 > 0$.

$$y_{22}^{rc} = y_{22}^{rc} = \frac{T-\bar{Q}}{2} = f(\bar{Q}, T)$$

(ii) The derivative of $\Pi_1(Pq)$
$\Pi_1(Pq) = P.(y_{11}(Pq,\bar{Q},T) + y_{21}(T,\bar{Q})) - C_1(y_{11}(Pq,\bar{Q},T)) - C_2(y_{21}(T,\bar{Q})) - P_q(y_{11}(Pq,\bar{Q},T) - \bar{q}_1) - \lambda(P,T,\bar{Q}).(y_{11}(Pq,\bar{Q},T) + y_{21}(T,\bar{Q}) + y_{12}(Pq,\bar{Q},T) + y_{22}(T,\bar{Q}) - T)$
$\frac{\partial \Pi_1(Pq)}{\partial Pq} = \frac{\partial y_{11}}{\partial Pq}P - C_1'\frac{\partial y_{11}}{\partial Pq} - [y_{11} - \bar{q}_1] - P_q\frac{\partial y_{11}}{\partial Pq} - \lambda.[\frac{\partial y_{11}}{\partial Pq} + \frac{\partial y_{12}}{\partial Pq}]$
As $\frac{\partial y_{11}}{\partial Pq} = -\frac{\partial y_{12}}{\partial Pq}$
$\frac{\partial \Pi_1}{\partial Pq} = \frac{\partial y_{11}}{\partial Pq}P - C_1'\frac{\partial y_{11}}{\partial Pq} - [y_{11} - \bar{q}_1] - P_q\frac{\partial y_{11}}{\partial Pq}$
(iii) $\Pi_1(Pq)$ concave
$\frac{\partial^2 \Pi_1}{\partial Pq^2} = \frac{\partial^2 y_{11}}{\partial Pq^2}(P - C_1' - P_q) - 2\frac{\partial y_{11}}{\partial Pq} < 0$
(iv) The manipulated price
$P_q^{rc}(\bar{Q},\bar{q}_1)$ is such $\frac{\partial \Pi_1}{\partial Pq} = 0$. Rearranging terms, we find Eq.(25).
(v) The variation of $P_q^{rc}(\bar{Q},\bar{q}_1)$
From Eq. (25), we set: $F(Pq,\bar{q}_1,\bar{Q}) = \frac{\partial y_{11}}{\partial Pq}(P - C_1' - P_q) - [y_{11}(Pq,\bar{Q},T) - \bar{q}_1]$.
Applying the Implicit Function Theorem we obtain:
$\frac{dP_q^{rc}}{d\bar{q}_1} = -\frac{\partial F/\partial \bar{q}_1}{\partial F/\partial P_q^{rc}} = -\frac{1}{\frac{\partial^2 \Pi_1}{\partial Pq^2}} > 0$, because $\frac{\partial^2 \Pi_1}{\partial Pq^2} < 0$.
$\frac{dP_q^{rc}}{d\bar{Q}} = -\frac{\partial F/\partial \bar{Q}}{\partial F/\partial P_q^{rc}} < 0$.

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