Regulating transgenic soybean production in Argentina

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July 11, 2017

Abstract

This article proposes a way for regulating transgenic soybean production in Argentina. Taking into account the broad range of negative externalities due to transgenic soybean production, global production should be first redirected toward non transgenic soybean. To do that, we investigate a subsidy for non transgenic soybean and production quotas for transgenic soybean. Considering the political and the economic situation in Argentina, we suggest that auctioned production quotas are high of interest whatever competition in the quota market. However, the regulator has to be aware that a raising rival's cost behavior can occur on the quota market although the output price cannot be changed. Finally we show that introducing a shadow cost of public funds leads to increase the optimal production level of transgenic soybean.

Keywords: Transgenic Soybean, Argentina, Environmental Regulation, Production quotas, Market Power

JEL classification : Q38 Q32 Q58

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 FAO database (FAOSTAT), this crop represents nowadays 58% of total cultivated land and 38% of agricultural production against respectively 30% and 24% in 2000. The oilseeds sector has thus gradually become a strategic sector of Argentina's economy and its dramatic productive performance has been the source of a great pride.

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However, the change in the structure of agricultural production has involved a broad range of damages in terms of agricultural practices, emission of pollutants, human health and welfare. As a result the long-term sustainability of the Argentina's specialization in transgenic soybean production became a matter of concern during the first decade of the 2000s. Most controversial issues concerns the environmental impact of transgenic soybean cultivation such as the intensification of agricultural land use, incomplete rotation patterns between the crops, expansion of the agricultural frontier at the expense of natural lands, and, above all, intensive use of glyphosate which results in soil contamination, air and water pollution, and health problems (Gras and Hernández, 2009; Gras, 2009; Leguizamón, 2013; Pengue, 2005). Transgenic soybean cultivation has also a social cost: a significant amount of labor has been displaced out of the agricultural sector, local rates of unemployment and income inequality have increased in the producing zones (Phélinas and Choumert, 2016).

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 myriad of farms which takes cropping decisions (Griffin and Bromley, 1982; Segerson, 1988; Helfand and House, 1995; Shortle and Horan, 2001). Most of them has focused on input taxes, input levels, and farming practices. However, the negative externalities of transgenic soybean production go far beyond pollution due to glyphosate. Hence, the problem of "overplanting" transgenic soybean is as one of regulating the output mix. Regulating output quantity would directly regulate not only the glyphosate but also promote a socially efficient production structure by correcting the ongoing resource re-allocation to transgenic soybean production. As agricultural production would stay focused on soybean, the revenue coming from export taxes would not change, which is highly important for public authorities.

An alternative policy instrument such as a "green" tax on a socio-environmental harmful product such as transgenic soybean could also be efficient. However, two raisons limits the relevance of this solution. Such a tax is unlikely to be implemented in Argentina, because soybean producers already face a high export tax (35%) which reduces the price they receive compared to the corresponding export price. In March 2008, the government tried to further raise this level up to 44% but the tax pressure was felt intolerable and punitive by producers. This resulted in a big conflict in which the producers started to protest and block roads. At the end, the government was forced to move back.

These events underline that a big challenge in implementing a regulation for transgenic soybean in Argentina is the political acceptability associated to policy intervention. Another constraint comes from the fact that the direct export tax has traditionally contributed in a big way to fueling the government budget. Therefore, the question addressed here is how to restrict transgenic soybean production with a high probability of acceptance, while preserving fiscal revenue in order to meet the debt service payment and other social expenses.

This paper is the first tentative to propose a way for regulating transgenic soybean in Argentina. Two tools are investigated: a subsidy for non transgenic

soybean and production quotas for transgenic soybean. We first question the potential of a subsidy for transgenic soybean but it would be difficult to raise funds to finance it in Argentina. A solution would be to delegate the payment of this subsidy to the market by the way of a market price premium for non transgenic soybean. But international conditions are not fulfilled today. Considering on the one hand the main political economic problem with soybean regulation in Argentina is that interest groups will lobby to retain their market share and profits and, on the other hand, the economic situation in Argentina, we argue that transferable production quotas is high of interest. Production quotas give considerable flexibility to the controlling authority in the initial allocation rules which makes it possible to control political acceptability. The potential acceptability associated to the different allocation methods is discussed as well as their economic efficiency. We also highlight the existence of a trade-of between political acceptability and social equity. It appears that auctioned quotas balance all these points. Moreover, production quotas of transgenic soybean also enables to reach the optimal production level of non transgenic soybean although this latter is not regulated. However, it is possible that the quota market be submitted to a market power. In this case we show that a raising rival's cost strategy can occur even if the soybean price cannot be changed. The production allocation is not more cost-effective and the regulator loses flexibility in initial allocation rules. However the first-best level of transgenic soybean is always reached. Finally, our framework is extended taking into account distortionary taxation that leads to a higher level of transgenic soybean production.

The remainder of this 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 model describing the laissez-faire situation and defining the first-best regulation. In Section 4 the use of a subsidy for non transgenic soybean is questioned. Section 5 investigates the potential of transferable production quotas for transgenic soybean to decentralize this first-best. Our framework is extended taking into account the existence of 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 in 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 method, massive applications of chemical inputs, and intensive mechanization of agricultural operations have constituted 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 the 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, has been driven by many factors. First, the weak protection of the intellectual property laws constituted a strong institutional factor which facilitated the expansion of transgenic soybean (Bisang & al 2006; Sztulwark & Braude, 2010; Pellegrini, 2013; Filomeno, 2013). The Argentinian law on the seeds and phylogenetic creations promulgated in 1973 protect the intellectual property rights little because it recognizes the right of the producers to replant their own cultivars. Accordingly, transgenic soybean seeds nor the glyphosate have been protected by a patent in Argentina. Moreover, a parallel market of seeds of transgenic soybean was set up little by little. The Argentinian producers thus could acquire 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; Moschini et al., 1999; Penna and Lema, 2002; 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 from 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 than to cultivate non transgenic soybean.

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

On its side, the government has shown little interest in fighting against the powerful agrarian lobby groups for two main reasons. First, there exists in Argentina a traditional class alliance between the landed elites and the political power (de Janvry, 1975). Second, farming is the motor of the nation's economy and soybean is the country's most important export commodity that makes a positive contribution to the Argentinian trade balance as well as a key crop which secures a high share of the government's revenue (15-20%). This explains that, until recently, there has been little recognition of the deleterious environmental and social impact of transgenic soybean intensive mode of production.

Yet, transgenic soybean cultivation generates a wide range of negative en-

vironmental 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 since 1996 from 13,9 million liters to 246 million in 2012 (CASAFE, 2012). This amount could reach more than 300 million liters for the campaign 2015/2016 according to estimates. This massive and often unreasoned increase in the use of glyphosate has been triggered by the expansion of the area cultivated in transgenic soybean but also by increased application frequencies resulting from pest resistance. Currently, there exists more than twenty listed adventitious species which present a resistance to the weed killers available on the market (Vial-Aiub, 2008).

Although the toxicity of glyphosate is controversially discussed, 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 watery fauna are destroyed (Casabé et al., 2007; Perez and al, 2007). In March 2015 the International Agency for Research on Cancer classified the glyphosate in A2 category, thus corroborating the observation of an increase in diseases (cancers, malformation of new born, allergies, respiratory illness, etc) in the rural population residing in the 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 the sensitive bio diverse ecoregions such as the Yungas or the Great Chaco (Gavier-Pizarro et al., 2012), have threaten indigenous and peasants' inhabitations. Rising violence linked to land grabbing has also been noted.

The network-based system of production previously described has triggered a strong movement of dissociation between landowning and land cultivation, a significant growth in the number of short-term land leasing agreements, and an increasing importance of sowing pools as renters. This aspect of the modelo sojero has been very controversially discussed in Argentina. It is argued that the increase in tenancy has given strong incentives for the intensification of land use and rapid conversion of rotational cropping patterns into permanent soybean production. Many studies highlight the detrimental impact of crop rotation abandonment on yields (Bacigaluppo et al., 2009; Caviglia and Andrade, 2010; Mudgal et al., 2010; Rótolo et al., 2015), whereas others emphasize the negative implications of indirect land tenure on fertilization, 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 undoubtedly contributed to reduce the labor absorption in agriculture. The technical jump introduced by biotechnologies associated with an intense mechanization of the production

process has destroyed many jobs at the farm level (Phélinas and Choumert, 2016). An increase in unemployment as well as the persistence of a high incidence of poverty in the villages and the rural cities pertaining to the transgenic soybean production zones have been recently highlighted (Gras and Bidaseca, 2010; Caceres, 2015).

3 The model

In this section we first describe the "laissez-faire" context, i.e. the situation in which producers' decision whether to grow transgenic soybean or conventional soybean is not constrained by policy regulation. We then define the first-best regulation which consists in setting physical restrictions on transgenic soybean production.

3.1 The "laissez-faire"

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 $C_1(y_1) < C_2(y_2)$, both costs functions being increasing and convex with $C_1'''(y_1) < 0$.[1][2] Available land is limited to T.[3] The production of y_1 (y_2) needs a surface y_1 (y_2) such as: $T \geqslant y_1 + y_2$.[4]

All the farms are assumed to be price-takers. The soybean price (denoted P) is set competitively on an international market, which determines a single price for transgenic and non-transgenic soybean.[5] In this context, the representative farm chooses the optimal level of transgenic and non-transgenic soybean production that maximizes its profit:

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

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

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

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

From (1) and (2), we obtain:

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

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[1] This condition always secures concavity in profit when we consider a regulation with imperfectly competitive quota market.

[2] As already quoted, transgenic soybean seeds nor the glyphosate have been protected by a patent in Argentina, reducing drastically their cost.

[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 think that it is less expensive to come back to non transgenic soybean than immediately adopting others culture. Moreover, substituting non transgenic soybean to transgenic soybean enables to not change the global soybean production and so, the export tax revenue.

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

It is assumed that the capacity constraint is 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 as 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 transgenic soybean, then the level of production can be very low. Observed transgenic soybean development in Argentina, triggered by its lower cost of production, is a salient illustration of these theoretical predictions.

3.2   The first-best

Assuming that there exists a functional relationship between level of transgenic soybean production and its externalities, let $D(y_1)$ be the total damage induced by the 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 firm's profit but also the environmental damage induced by the production of transgenic soybean.[7] This function can be written as the following:

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

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

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

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

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

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

Assuming that the constraint on available land is bounded, it follows that $\lambda^{**} > 0$ and $y_1^{**} + y_2^{**} = T$. 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 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.

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

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

4   Subsidy of non-transgenic soybean

To decentralize the first-best production level of transgenic soybean, the regulator can choose to subsidize non-transgenic soybean. Setting a subsidy S per unit of non-transgenic soybean, the profit of the representative farm can be written as follows:

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

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

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

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

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

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

If $S = D'(y_1^s)$, Eq. (11) is the same as Eq. (8) when $\lambda^s > 0$. Thus a well-designed subsidy for non-transgenic soybean can reach the first-best outcome. The main disadvantage is that the regulator has to find a budget to finance this subsidy. This alternative is unlikely to be implemented in Argentina because of an explosive debt accumulation resulting in debt service payments that still reach 4,7% of GDP in 2016 (Cibils, 2011). The fiscal effort to meet these payments is expected to require large tax revenues and/or cutting spending (IMF, 2016). In this context subsidizing non transgenic soybean competes with other fiscal resources devoted to programs that transfer wealth to the poor, a fact that could raise a problem of acceptability in Argentina society.

However, the payment of this subsidy can be transferred to the private market. Indeed there exists an international market price premium for non-transgenic soybean but this latter does not get back non-transgenic producers (Fok and al., 2010). A way to implement this transfer would be to make sure that the payment of this premium goes back to non-transgenic producers. That would achieve the first-best without supplementary costs for the taxpayers. However the Cartagena Protocol on Biosafety requires traceability and labeling for distinguishing transgenic and non transgenic soybean. But supply chain certification is very costly. Besides there is no rules for separating transgenic from non transgenic soybean in agricultural parcel, leading to a contamination risk of non transgenic soybean. Finally, non transgenic soybean producers renounce to obtain the price premium leading to an increase in transgenic soybean production. Without international rules to organize both supply chains for transgenic and non transgenic soybean, transgenic soybean will not be regulated by the market price premium.

5 Tradeable production quotas

Let us now consider that the instrument chosen by the regulator takes the form of tradeable production quotas. We relax the assumption of a representative firm and consider N identical firms. In order to control the level of transgenic soybean production, the regulating authority issues a given amount of production quotas. For simplicity, each quota gives the right to produce one unit of transgenic soybean. To hold a quota is a legal constraint which is enforced by law.[8] Confronted with this new regulation, each agricultural firm has to hold an amount (q_i) of production quotas corresponding to its desired level of production such as $q_i = y_{1i}$. Production quotas may be freely issued or sold to farms in a primary market. They also may be traded on a secondary market at a competitive price P_q.

5.1 A competitive quota market

If the optimal level of transgenic soybean production is achieved with the setting of the adequate level of production quotas, the different levels of production between firms remain a crucial point. In the following, we cheek the extent to which different initial allocation of quotas makes it possible to reach the criteria of cost-efficiency. Since a major issue in setting production quotas is the way they are allocated, various options are discussed. In brief, they are (a) a free lump-sum allocation; (b) an auction; and (c) an output based allocation. In the following, we check the extent to which different initial quota allocation achieve the first-best as well as the distributional effects and, accordingly, their political acceptability.

5.1.1 A free lump-sum allocation

In a free lump-sum allocation the regulator allocates production quotas

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

freely to farms. Quotas are distributed following an appropriate criteria, be it a benchmark of past-level production (one say "grandfathering"), other past criteria, or the political influence of interest groups. Farms are allowed to trade quotas in a secondary market. Each firm receives $\bar{q}_i$ such as $\bar{Q} = \sum_{i=1}^{N} \bar{q}_i$. Integrating this new constraint in the cropping decision, Farm i chooses respectively y_{1i} (y_{2i}) production level of transgenic soybean (non transgenic soybean). The new profit function is:

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

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[8] We assume that penalty in case of non-compliance is sufficiently high to induce agricultural firms to respect this constraint.

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

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

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

Solving (13) and (14) yields:

$$C'(y_{1i}^{rf}) + P_q^{rf} = C'(y_{2i}^{rf}) \tag{16}$$

Since farms can transfer their quotas among one another, if the desired level of production exceeds (is inferior to) the allowance received i.e. $(y_{1i}^{rf} - \bar{q}_i) > 0 \, (< 0)$, the farm i will buy (sell) quotas. The resulting exchanges on the secondary market set the price of the production quota P_q^{rf} such as: $\bar{Q} = \sum_{i=1}^{N} y_{1i}^{rf}$. The total number of production quotas being $\bar{Q} = y_1^{**}$ we necessary have $P_q^{rf} = D'(\sum_{i=1}^{N} y_{1i}^{**})$. Therefore, the competitive price of quotas creates appropriate incentives for farms to choose the "good" level of transgenic and non-transgenic soybean production such as $\sum_{i=1}^{N} y_{1i}^{rf} = y_1^{**}$ and $\sum_{i=1}^{N} y_{2i}^{rf} = y_2^{**}$.[9] The global quantity of production quotas sets the first-best level of transgenic soybean whereas tradeable quotas enables to reach the cost-efficiency criteria.

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. Hence, as we expected, the introduction of production quotas for transgenic soybean changes the relative share of transgenic versus non transgenic soybean in total production whereas there is no direct regulation for non transgenic soybean

In Equations (13) and (14), the initial distribution of production quotas does not appear. So whatever the amount of quotas any producer initially receives, the final distribution of transgenic soybean production does not change. This is because the initial allocation of quotas is equivalent to a lump sum subsidy independent of production levels. It is thus just a distributional issue which provides flexibility in the allocation of rents. This result is consistent with Montgomery (1972).

Thus a free lump sum allocation is very appealing for the regulator who can issue production quotas according to different criteria that achieve the desired reduction in the transgenic soybean production. He may try to favor firms which already produce non-transgenic soybean by giving them more quotas than others or giving them the whole quotas and nothing to others. He may also give equal shares to transgenic soybean producers or allocations in proportion of their past production (or land cultivated). The allocation rule choice depends on whether

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[9] As $Y_2^{rf} = T - Y_1^{**}$, we necessary have $Y_2^{rf} = Y_2^{**}$.

the regulator will try to implement an allocation scheme that do not result in political fight or a scheme that do not have distributional impact on producers' cost and profits.

The Argentine rural sector is socioeconomically fragmented but 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 played a leading role in the expansion of transgenic soybean cultivation. In contrast, small farmers make up the majority of the FFA's, CRA's membership who have the widest social base. Both associations usually battle for protecting the interests of small/medium producers, regularly through the use of strikes.

The coalition of these four key interest groups against the regulation is not unlikely. They have proved their rallying capacity in the past in reaction to the government's proposal of increases in taxes on grain and oilseeds in 2008. Hence the question of acceptability appears crucial. Giving the inherent rent-seeking nature of the four agricultural organizations, it is necessary to convince, with economic arguments, the one with the greatest political power. A distributional design based on historical output appears a possible option, because it will favor existing producers and convey rents to the largest ones. As a result, this allocation rule may find support from the largest producers towards the regulation since it would lead to the satisfaction of the SRA's influent members' demands what amounts to supporting well-established big producers. However, past-based distribution may be perceived to be unfair by many small or medium producers who will encounter difficulties in maintaining or increasing their market share. Grandfathering might thus result in a long-lasting fight of the other three interest groups for capturing a greater share of the allocation or seeking exemptions. This may end in high amounts of time lost to lobbying and probably delays in implementation.

Finally, grandfathering might have an important shortcoming. The initial allocation of quotas may induce the creation of potential market power, depending on the bargaining power of producers. We show in Section (5.2), that a market power on the production quota market leads to an inefficient outcome, as demonstrated in a seminal paper by Hahn (1984) for tradeable pollution rights.

5.1.2 An auction

Instead of a free lump-sum allocation, the social planner could auction the permits. This alternative is an interesting one in Argentina where agricultural has long been an essential source of fiscal revenue. Argentina has accumulated an explosive debt resulting in debt service payments that still reach 4,7% of GDP

in 2016 (Cibils, 2011). The fiscal effort to meet these payments is expected to require large revenues and/or cutting spending (IMF, 2016). When quotas are auctioned, the regulator raises a revenue in issuing $\bar{Q} = y_1^{**}$ production quotas. The initial quotas distribution is null ($\bar{q}_i = 0$, $\forall i$), so each farm has to buy the right to produce transgenic soybean. The firms' profit is similar to that with free lump-sum allocation, setting $\bar{q}_i = 0$. As the conditions of Equation (16) under free lump allocation are satisfied, auctioning quotas enables to reach the first-best while raising revenue.

However, the main political economy disadvantage is that auctioned quotas might face stronger political opposition than grandfathering. There are good reasons to fear a big fight from interest groups who constituted in the very powerful associations already mentioned, more concerned with protecting the income of their members than social and environmental considerations.

A way of reconciling divergent public and private interest would be to use the income from auctioned quotas to cut the very unpopular taxes on soybean exports and/or to compensate the shrink in firms' profit resulting from the regulation. Moreover equity can be better achieved through the use of the revenue resulting from auction quotas. It could be used to compensate for the negative externalities of the transgenic soybean cultivation : such as health damage induced by glyphosate, or to provide assistance to fired workers to change industries. The revenue could also be used to finance additional public goods or simply correcting fiscal imbalances. In all cases, revenue has to be issued under lump-sum transfer in order to avoid strategic behavior.

5.1.3 A free output-based allocation

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

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

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

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

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

From (17) and (18) we have:

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

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), $y_{1i}^{ob} > y_{1i}^{rf}$. Producing one unit of transgenic soybean costs P_q production quotas but generates a gain corresponding to $P_q.f'(y_{1i})$. Under this allocation rule, there is thus an additional incentive to produce transgenic soybean. As a result, the output-based distribution does not implement the cost-efficiency outcome. However, since it can favor existing producers this allocation rule may find support from largest producers towards the regulation.

5.2   An imperfectly competitive quota market

We assumed above that production quotas are tradeable on a competitive secondary market. This assumption leads to a cost-effective solution with lump-sum initial allocation and auction. However firms have to face diminishing returns resulting from the regulation. As the soybean price is internationally set, they cannot modify this price at their advantage. However firms may try to reconstitute their profit by exerting a market power on the production quota market. A "predatory firm" could induce rivals to exit the market by raising their costs. This is a non price predatory conduct (Salop and Scheffman, 1983). As production quotas are needed to produce, they can be used as exclusionary rights. According to Krattenmaker and Salop (1986-1987), the purchaser can acquire a representative portion of the quota supply, withholding that portion from rivals thereby driving up the market price for the remainder of the quota still available to rivals. This "supply squeeze" or "quantitative foreclosure" is the result of unfair competition to obtain the right to produce.

Manipulating the quota price to reduce its conformity cost should be a serious concern in Argentina. According to Arin and Perez (2011), although the primary production includes numerous producers (around 73 thousand), only 6% of producers contribute to 54% of the production. This reduced group, representative of the large scale agriculture (pools of sowing), was consolidated as a new actor in the last decade. It is not unlikely that these very powerful associations 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 wonder if a dominant firm on the production quotas will just use its market power to minimize its conformity cost with soybean regulation or to raise rival's costs. To explore this idea, we assume two representative firms or two groups of firms. Firm 1 (for example, a "sowing pool") will adopt a non-competitive behavior on the secondary market whereas Firm 2 (the competitive fringe) will act as a price-taker. First, the dominant firm sets the price of the production quotas. Then, each firm chooses its optimal level of production taking into account both soybean and quota prices as given. This problem has to be solved using backward induction (Sartzetakis, 1994 and 1997).

5.2.1 The second step

In this step, each firm chooses its level of production taking both prices as given (P_q and P). As production decisions have to be compatible with the quota market equilibrium, the dominant firm has to take into account this constraint in its profit. Let be γ the associated Lagrangian multiplier. The dominant firm's profit can be written as follow:

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

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

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

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

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

The levels of production for Firm 2 (y_{21} and y_{22}) are given by Eqs. (13) and (14). Solving this system of Equations given by Eqs. (21), (22), (23), (24), (13) and (14) in Appendix, we find: $y_{21}^{rc} = y_{22}^{rc} = f(T, \bar{Q})$, $y_{11}^{rc} = f(Pq, \bar{Q}, T)$, $y_{12}^{rc} = f(Pq, \bar{Q}, T)$, $\lambda^{rc} = f(P, T, \bar{Q})$ 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 firm increases with the production quota price, we can expect that this firm will try to increase this price in order to expand its production level.

5.2.2 The first step

In the first step, the dominant firm sets the price of the production quota. 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 price satisfies the following equation:

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

From Eq. (25), the optimal quota price is such that the net demand of the dominant firm be equal to the change in its marginal profit. Solving Equation (25) we obtain the manipulated price:

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

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 not anymore independent of the initial allocation.[10] Thus, the result obtained with a competitive market of production quotas in Section 4.1.1 is challenged. The higher the initial distribution, the higher the manipulated price.

The regulator can use the initial distribution to restore the first-best outcome. Assuming that the regulator sets an initial distribution such that the dominant firm does not intervene on the production quotas, *i.e.* $\bar{q}_1' = y_{11}^{rf}(Pq, \bar{Q}, T)$. The regulator grants the dominant firm a sum 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. Thus the regulator cannot restore the first-best with the initial allocation $\bar{q}_1'$. He would better choose another allocation, such as:

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

So the regulator can restore efficiency in the detriment of equity considerations. Without this key initial distribution, production quota market does not implement cost-efficiency.

Two kinds of market manipulation can be distinguished in the economic literature (Misiolek and Elder, 1989). If the dominant firm just uses its market power on the permit market to reduces its conformity cost, it exerts a simple manipulation. But if this firm seeks to obtain a advantage by manipulating the permit price, it exerts a exclusionary manipulation. Equation (25) shows that the manipulated price takes into account non only the production quota market but also the production field. Thus the dominant firm does not just use its market power on the production quotas in order to minimize its conformity cost. It also tries to raise the price in order to increase rival's cost, acting as a predatory firm.

According to Salop and Scheffman (1987), the raising rival's cost strategy aims to increase the output price. It is always the case in studies about tradeable pollution permits (Misiolek and Elder, 1989, Sartzetakis, 1994, 1997, Eschel, 2005). In our analysis, we show that this strategy can be pursued although the output price cannot be changed because set on an international market. Production quotas are first specific inputs without that production is impossible. Overbuying quotas is enough to exclude competitors and the consecutive increase in the quota price just reinforces exclusion. The benefit of this strategy comes from the manipulated quota market and from increased production. A way of limiting this behavior is to auction quotas.
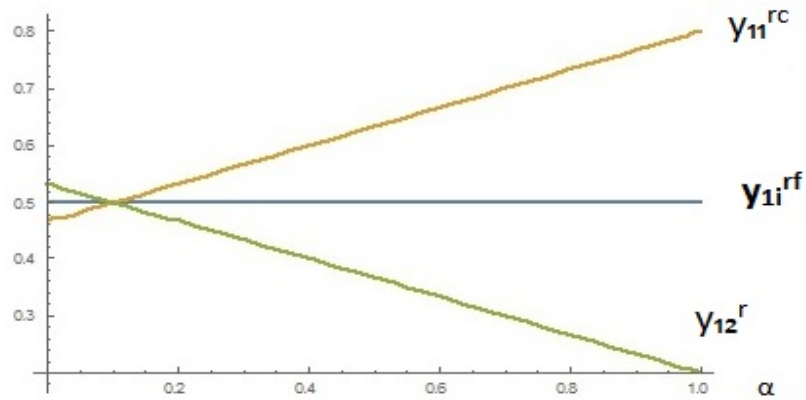
In order to best understand the effects of the dominant firm's strategy, we use a numerical example. We set $P = 1$, $\bar{Q} = 1$, $T = 1.6$, $C_1(y_{1i}) = \frac{y_{1i}^2}{2}$, $C_2(y_{2i}) = y_{2i}^2$ and $\bar{q}_1 = \alpha \bar{Q}$ with $\alpha \in [0; 1]$. Results are summarized in Figure 1 and Figure 2.

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

2
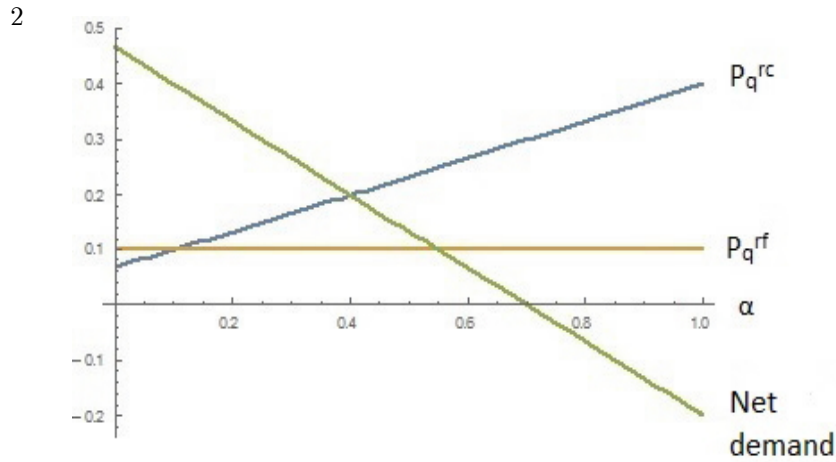
Price variations and net demand of the dominant firm

manip

Transgenic soybean production levels under perfectly and imperfectly
competitive quota market

The manipulated quota price, the competitive quota price and the net de-
mand of the dominant firm are represented in Figure 1 depending on the initial
allocation (α). Transgenic soybean production levels under competitive and non
competitive quota market depending on α are given in Figure 2. The dominant
firm strategy leads to an increase in the quota price and in its production level
to the detriment of the competitive fringe. The more the initial allocation, the
higher the quota price and the firm 1's production level. If $\alpha = 0.7$, the domi-
nant firm does not intervene on the quota market but the price is higher than
its competitive level. From both Figure 1 and Figure 2 we observe that if this

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firm receives an initial allocation such that $\alpha = 0.1$, the market equilibrium will reach the competitive one.

The net demand of the predatory firm $(y_{1i}^{rf} - \bar{q}_1)$ 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 firm 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 the simple manipulation is to reduce (increase) the price when the dominant firm is a buyer (a seller) whereas that of the exclusionary manipulation is to increase it. Thus if the dominant firm exerts a monopoly power in the quota market, both manipulations lead to increase the price. But if it initially exerts a monopsony power, the aim of the simple manipulation is to reduce the permit price whereas that of the exclusionary manipulation is to increase it. The resulting manipulated price depends on both effects. Finally, the quota price can be higher than its competitive value even though the firm acts 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 used to increase the revenue of the government, and on the type of price regulation.[11] Let us noted β the marginal cost of public funds. When the regulator raises \$1, the society pays \$$(1 + \beta)$. Accordingly, if production quotas are sold, the revenue obtained 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 firm, the regulator sets a new optimal level of production quotas that maximizes the following welfare function:

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

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

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

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

From (27) and (28), we find:

$$C_1'(y_1^{dt}) + D'(\sum_{i=1}^{N} y_1^{dt}) - \beta P_q^{dt} = C_2'(y_2^{rf}) \tag{29}$$

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

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[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.

distortionary taxation prevents the regulator to reach the first-best. Taking into account the tax payers' welfare thus leads to allow a higher production of transgenic soybean. As such, this kind of taxation is detrimental for environmental and social considerations.

7 Conclusion

Transgenic soybean production increased Argentina's economy dependence on soybean production and exports, raised social questions, and induced numerous negative externalities such as deforestation, soil pollution as well as health problems resulting from the intensive use of the glyphosate. Considering the environmental, health and social costs arising from transgenic soybean expansion, policy action is needed to promote a socially optimal output mixture. However, transgenic soybean production has become one of the strategic components of Argentina's economy, as well as in the country's international positioning. In addition farms have made expensive investment to produce transgenic soybean. It will be thus quite difficult to regulate this crop, and the government will undoubtedly have to engage in the struggle that usually precedes any environmental regulation.

This paper provides a formal model for transgenic soybean regulation. We propose a regulation based on output instead on input. We begin by setting the optimal level of transgenic soybean. A well-designed subsidy on production of non transgenic soybean decentralizes the first-best level of transgenic soybean but raises the problem of its finding. Another way to reach the first-best would be to make sure that the non-transgenic soybean market premium goes back to the producer, which is not the case today. Moreover, the revenue of export tax will increase, which would be appreciated by public authorities. However, the premium has to be exactly equal to the level of the marginal damage induced by the transgenic soybean. It will occur by chance. But this solution suggests international rules to organize both distribution chains as specified by the Cartagena Protocol on Biosafety, which is not possible today. So we investigate the potential of tradeable production quotas to regulate transgenic soybean.

As the soybean global production is not changed, the revenue coming from export taxes stays the same, which is an important point for public authorities. Since the distributional question of the regulation is critical for the political feasibility, we examine different initial allocations for quotas. As far as the political economy of regulation is concerned, we show that whereas a free lump-sum allocation is likely to yield political acceptability, an auction should be preferred if equity is a concern although that could raise strong political opposition. Equity and political opposition can be satisfied by a well-designed auction revenue rebate. For example, the revenue can be used to compensate losses in firms' profit or to compensate the damage induced by the massive use of glyphosate. However the agricultural sector is such that a raising rival's cost strategy may occur on the production quota market. We show that this strategy is profitable for a predatory firm whereas the output price cannot be changed. This result

is contrary to the economic literature about this question. The first-best level of transgenic soybean production remains achieved, but not cost-efficiency. A way to limit this predatory strategy is to auction quotas.

Finally, we consider an extension of our framework. We assume a distortionary taxation in the economy. In this case, only a second-best regulation is reached because a larger amount of production quotas will be sold than in the first-best. Hence, taking into account the tax payers' welfare is detrimental for environment.

Further research could extend our work in two directions. A second step in the soybean regulation would be to increase the share of other agricultural productions at the expense of the both transgenic and non-transgenic soybean production. Another question that needs to be addressed, given that Argentina is the third world producer of soybean and the first exporter of soybean pellets, is the extent to which reducing Argentinian global soybean production may impact the soybean world price.

8 Appendix

The "laissez-faire" From (1) and (2) we have: $y_1 = (c'_1)^{-1}(P - \lambda)$ and $y_2 = (c'_2)^{-1}(P - \lambda)$. λ is such that $T - (c'_1)^{-1}(P - \lambda) - (c'_2)^{-1}(P - \lambda) = 0$.

A free lump-sum allocation Assuming $N = 2$, from Eq. (12), (13), (14) and (15), we find: $y_{11} = y_{12} = (c'_1)^{-1}(P - P_q - \lambda)$, $y_{21} = y_{22} = (c'_2)^{-1}(P - \lambda)$, $\bar{Q} = y_{11} + y_{12}$ and $T = y_{11} + y_{12} + y_{21} + y_{22}$. Solving this system we obtain:

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

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

$$\lambda = P - c'_2(\frac{T - \bar{Q}}{2})$$

$$P_q = c'_2(\frac{T - \bar{Q}}{2}) - c'_1(\frac{\bar{Q}}{2})$$

From (16), we set $F(y_{1i}, y_{2i}, P_q) = C'_1(y_{1i}^{rf}) + P_q^{rf} - C'_2(y_{2i}^{rf})$. Applying the Implicit Function Theorem, we find: $\frac{\partial y_{1i}^{rf}}{\partial P_q} = c''_1(y_{1i})^{-1} < 0$ and $\frac{\partial y_{2i}^{rf}}{\partial P_q} = c''_2(y_{2i})^{-1} > 0$, $\forall i$.

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 $\Pi_1(Pq)$

$\Pi_1(Pq) = P.(y_{11}(Pq, \bar{Q}, T) + y_{21}(T, \bar{Q})) - C_1(y_{11}(Pq, \bar{Q}, T)) - C_2(y_{21}(T, \bar{Q})) - P_q(y_{11}(Pq, \bar{Q}, T) - \bar{q}_1) + \lambda(P, T, \bar{Q}).(T - y_{11}(Pq, \bar{Q}, T) - y_{21}(T, \bar{Q}) - y_{12}(Pq, \bar{Q}, T) - y_{22}(T, \bar{Q}))$

$\frac{d\Pi_1(Pq)}{Pq} = \frac{\partial y_{11}(Pq)}{\partial Pq}P - C_1'\frac{\partial y_{11}(Pq)}{\partial Pq} - [y_{11}(Pq) - \bar{q}_1] - P_q\frac{\partial y_{11}(Pq)}{\partial Pq} - \lambda.[\frac{\partial y_{11}(Pq)}{\partial Pq} + \frac{\partial y_{12}(Pq)}{\partial Pq}]$

As $\frac{\partial y_{11}(Pq)}{\partial Pq} = -\frac{\partial y_{12}(Pq)}{\partial Pq}$

$\frac{d\Pi_1(Pq)}{Pq} = \frac{\partial y_{11}(Pq)}{\partial Pq}P - C_1'\frac{\partial y_{11}(Pq)}{\partial Pq} - [y_{11}(Pq) - \bar{q}_1] - P_q\frac{\partial y_{11}(Pq)}{\partial Pq}$

(iii) $\Pi_1(Pq)$ concave

$\frac{\Pi_1^2(Pq)}{\partial Pq^2} = \frac{\partial^2 y_{11}(Pq, \bar{Q}, T)}{\partial Pq^2}(P - C_1' - P_q) - 2\frac{\partial y_{11}(Pq)}{\partial Pq} < 0$

(iv) The manipulated price

$P_q^{rc}(\bar{Q}, \bar{q}_1)$ is such $\frac{d\Pi_1(Pq)}{Pq} = 0$. Rearranging terms, we find Eq.(25).

(v) The variation of $P_q^{rc}(\bar{q}_1, \bar{Q})$

From Eq. (25), we set: $F(Pq, \bar{q}_1, \bar{Q}) = \frac{\partial y_{11}(Pq, \bar{Q}, T)}{\partial Pq}(P - C_1' - P_q) - [y_{11}(Pq, \bar{Q}, T) - \bar{q}_1]$. Applying the Implicit Function Theorem we obtain:

$\frac{dP_q^{rc}(\bar{q}_1)}{d\bar{q}_1} = -\frac{\partial F(Pq, \bar{q}_1)/\bar{q}_1}{\partial F(Pq, \bar{q}_1)/P_q^{rc}} = -\frac{1}{\frac{d^2\Pi_1}{Pq^2}} > 0$, because $\frac{d^2\Pi_1}{Pq^2} < 0$.

$\frac{dP_q^{rc}(\bar{q}_1)}{d\bar{Q}} = -\frac{\partial F(Pq, \bar{q}_1)/\bar{Q}}{\partial F(Pq, \bar{q}_1)/P_q^{rc}} < 0$.

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