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REGULATING TRANSGENIC SOYBEAN PRODUCTION IN ARGENTINA: THE ROLE OF AGRO-ASSOCIATIONS

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Abstract

Argentina's economy is organized mainly around the export of transgenic soybeans. This production is associated with several environmental and social costs. This article investigates transgenic soybean production regulation possibilities, which fulfills efficiency, acceptability, and feasibility by directly controlling production levels. Production quota markets are promising because they make it possible to implement cost-effective production. However, Argentina's agricultural sector is organized into large agro-associations with significant political power. The exercise of market power could challenge the attractive properties of production quota markets. This article considers the possibility of these organizations manipulating the quota market to capture a larger share of production. The production quota market could give rise to "raising rivals' costs" behavior. Contrary to the existing literature, this article shows that this strategy is profitable, even though the price of transgenic soybeans is fixed on international markets. To restore efficiency in production levels while preserving policy acceptability, we propose to auction production quotas with an adequate rebate revenue. Alternatively, initial quota allocation can be hybrid. The initial allocation chosen will depend on the trade-off between efficiency and acceptability of the environmental policy. Thus, while proposing a specific and adapted regulation for transgenic soybeans in Argentina, this article contributes to the knowledge of tradeable production quotas, which are almost less analyzed in the economic literature.

Keywords

Transgenic Soybean, Argentina, Glyphosate, Environmental Regulation, Production Quotas, Market Power

JEL classification: Q38, Q32, Q58

1. Introduction

In Argentina 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.

Although the adoption of genetically modified (GM) crops has had significant macro and micro economic benefits (Bennett et al, 2013; Quaim, 2009; Phélinas and Choumert, 2017), the long-term sustainability of Argentina's specialization in transgenic soybean production has recently been questioned (Carreno et al., 2012; Leguizamon, 2013). The most controversial issue relates to the environmental impacts of transgenic soybean cultivation, such as the intensification of agricultural land use (Caviglia and Andrade, 2010), incomplete crop rotation patterns (Rotolo et al., 2015), expansion of the agricultural frontier at the expense of forests (Fehlenberg et al., 2017; Gasparri et al., 2013), and the intensive use of glyphosate. This herbicide, which regulates weeds growth, is suspected of contaminating soils (Peruzzo et al., 2008) as well as air (Astoviza et al., 2016) and water (Lupi et al., 2015; Gonzalez et al., 2014). The toxicity of glyphosate is still a very controversial topic and the empirical evidence is mixed. Whereas some studies did not find any statistical evidence of an association between health problems and glyphosate exposure (Andreotti et al., 2018), respiratory illnesses, higher incidences of cancer or offspring defects resulting from aerial spraying have been reported (Gallegos et al., 2016; Shinasi and Leon, 2014;

Botta et al., 2011).

When externalities are identified, the economic literature justifies regulation policies in order to correct market distortions. Government intervention to promote a more sustainable agriculture in Argentina would seem to be a necessity, but for many reasons we develop in Section 2, has not yet been given adequate attention. We will see in Section 3 that taking into account environmental damages lead to a reduction in transgenic soybean production level in favor of non-transgenic soybean. So this article is a first attempt to regulate the output mix in Argentina. If the question of the regulation of transgenic soya has not yet arisen in Argentina, Mexico has just taken a radical stance on transgenic maize. Beginning in 2021, the Mexican government announced a three-year ban on the cultivation and import of transgenic corn as well as the use of glyphosate, in the name of the defense of indigenous corn and food sovereignty of the country. Indeed when damages are uncertain, some researchers argue for a precautionary approach on the environmental risks of GMOs (Alasken and Myhr, 2005). In particular, spatial external effects could be so large that they may eliminate the planting of traditional varieties (Munro, 2008). One can think that Mexico has applied this precautionary principle, which seems an implausible solution for Argentinean transgenic soybean.

Most of the time, the regulators intervene to regulate pollution problems (Pigou, 1932; Crocker, 1966 and Dales, 1968). In this case, the regulatory instruments deal with polluting emissions. The regulator can also intervene to modify consumption behaviors such as alcohol consumption, generating negative externalities (Griffith et al. 2018). Production activity can also be directly regulated by using, for example, production quotas. Production quotas are not a widespread tool in our economies. Used in Canada for boilers, eggs and turkeys, in the European Union for milk, production quotas aim to stabilize the good price (Chen and Meilke, 1996). As far as transgenic soybean is concerned, it is a question of regulating a level of production. In order to give farmers flexibility, we propose, as a first step, to regulate the amount of transgenic soybean produced instead of banning it.

There are different modes of intervention that would regulate the produced quantity of transgenic soybean as a tax on transgenic soybean production, a subsidy for the production of non-transgenic soybean or tradable production quotas for transgenic soybean. If these tools would be theoretically equivalent in a perfectly competitive world, they may have different economic consequences in terms of efficiency, acceptability and feasibility taking into account the economic situation of the country. We will discuss in Section 2 the use of a tax on the production of transgenic soybeans or a subsidy on the production of non-transgenic soybeans. As the supply of soybeans seems to be rather inelastic to taxes, a tax would be ineffective. The economic and social situation in Argentina and in particular its debt invites us to reject subsidy. We propose to implement tradeable production quotas in order to regulate transgenic soybean production. With a specific initial endowment, tradeable production quotas could obtain acceptability by a specific use of the initial endowment, compatible with the Argentinean economic situation.

The implementation of a market for transferable pollution quotas has been largely discussed in the economic literature, particularly the conditions for its efficiency. When it works competitively, emissions are reduced where it is least costly, satisfying the least-cost efficiency criterion. Montgomery (1974) shows that this result is achieved regardless of the initial distribution of allowances. The allowance market therefore allows the regulator great flexibility to distribute allowances according to its objectives without affecting the efficiency of the market.

However, these results no longer holds under imperfect competition. The literature distinguishes between simple manipulation and exclusionary manipulation. When a firm engages in simple manipulation of the allowance market, it uses its market power just to minimize its environmental compliance costs (Hahn, 1984; Westskog 1996). A firm may realize that by manipulating the price of allowances it will be able to gain an advantage in the good market. In this case, it is exercising exclusionary manipulation (Misiolek and Elder, 1989; Von Der Fehr 1993; Sartzetakis 1994, 1997). Exclusionary manipulation is based on raising rival 's cost strategies. A "predatory farm" could also induce rivals to exit the market by raising their costs. These studies assume a dominant position in the good market.

While manipulation by exclusion is well described in the theoretical economic literature, there is no empirical support for this strategy. One assumption supporting exclusionary manipulation is that firms cannot produce without pollution quotas. However, firms can adopt pollution-reducing technologies in order to avoid the need for pollution quotas, which is not possible with production quotas.

So the use of production rather than pollution quotas changes the analysis somewhat, specially in the Argentine agricultural sector. According to Marin and Perez (2011), although the primary production in Argentina comprises a large number of producers (around 73 thousand), only 6% of producers account for 54% of the production. Moreover the Argentina rural sector is well organized through four key agro-associations. So the probability that some farms may try to manipulate the production quota price is high. We can expect that farms collude by setting up a cartel. As the soybean price is internationally set, the cartel could not influence market price on their own. The aim of this article is to investigate the consequences of a possible market power in the production quota market in this specific Argentinean context, and, notably under a competitive international soybean market and limited agricultural land surfaces.

We show that the cartel can use its market power to gain an advantage in the product market, even though the product market is competitive. In this case, the allocation of production levels is no longer efficient among firms. Moreover, the final allocation of production levels depends on the initial allocations of production quotas. The benefit of this strategy for the cartel comes from manipulation of the quota market and from increased production. In order to restore efficiency in production levels while preserving policy acceptability, we propose to auction production quotas with an adequate rebate revenue. Alternatively, initial quota allocation can be hybrid. The initial allocation chosen will depend on the trade-off between efficiency and acceptability of the environmental policy. Thus, while proposing a specific and adapted regulation for transgenic soybean in Argentine, this article contributes to the knowledge of tradeable production quotas, almost less analyzed in the economic literature.

The remainder of the paper is organized as follows. Section 2 gives an overview of transgenic soybean production in Argentina, explaining its expansion, its negative externalities and discuss the need and the kind of possible transgenic soybean production regulation. In Section 3 we introduce the assumptions of our theoretical framework describing the "laissez-faire" situation and defining the first-best regulation with a competitive production quotas. Section 4 investigates market power on the market of transgenic soybean production quotas. Section 4 presents our concluding remarks.

2. The Transgenic Soybean in Argentina: Its Expansion, Its Negative Externalities and The Need for Regulation

This section describes the expansion of transgenic soybean in Argentina as well as the resulting negative externalities induced. We then discuss different possible instruments of regulation and conclude that implementing production quotas for transgenic soybean would be adequate within the Argentinean context.

2.1 The rapid expansion of transgenic soybean in Argentina

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 (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, a vast campaign of promotion of biotechnologies on behalf of the scientists, the agri-biotech firms, multinational farms and export-oriented farmers, 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.

2.2 Transgenic soybean in Argentina and its negative effects

Transgenic soybean cultivation generates a wide range of negative environmental and social externalities. One of the negative impacts of transgenic soybean cultivation arises from the 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 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, as mentioned in the introduction: soil, air, water contamination and human health problems.

The extension of GM soybean cultivation into more marginal areas has also raised another major ecological concern. The evidence suggests that GM soybean crop has been the main deforestation driver in Argentina, either directly or via displacing cattle ranching from the Pampa region to the deforestation frontiers, especially in the four Northern provinces that constitutes the Chaco region (Fehlenberg et al., 2017; Gasparri et al., 2013). The resulting extensive loss of forest has triggered a large destruction of valuable ecosystem services, loss of species richness and regional climate change. Stopping or at least slowing down the forest loss implies that policies conservation must target not only cattle ranching but also soybean production.

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. 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). Thus, it seems that the "modelo sojero" is today questioned.

2.3 A need for regulation?

So far, the government has shown little interest in regulating agricultural production for three main reasons. First, there is a traditional class alliance in Argentina between the landed elites and the political powers. 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. They are the interest group that potentially has the strongest control over the regulatory process. 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. However, 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. In this case, the conventional theory of regulation tells us that their preferences have to be taken into account that if a regulatory policy is to be adopted (Stigler, 1971)

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%). 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 (if any) and safety issues are more likely to affect foreign consumers.

However, social movements against aerial spraying have recently emerged among the residents of farming communities in the Pampa region (Leguizamon, 2016). Consumers in some destination markets (the European Union in particular) exhibit high level of concern for transgenic soybean products. As a result, the European Union has imposed severe restrictions on food and feeds imports that may contain genetically modified organisms through strict labeling standards of GM products. In addition, since the European Union is one of the main export markets for Argentina (21% of soybean exports), any trend towards stricter regulation would possibly shut down the European Union's market for Argentinian GM soybean. This growing internal and external opposition to GM soy makes the adoption of environmental-friendly agricultural policy more likely in Argentina. A regulation could be designed so as to both secure the State's revenues and attract the most influent producers' political support.

2.4 What kind of regulation?

Traditionally, economic theory proposes to implement policies to regulate pollution levels. Our case is a little bit different, since it is a question of directly regulating production, even if this is not very widespread in the economic literature. We can therefore think about adapting instruments normally based on pollution to production. For example, transgenic soybean production could be taxed or non-transgenic soybean production subsidized. Another way would be to directly control the level of production of transgenic soybeans through production quotas.

First of all, two factors limit the relevance of a tax implementation 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 and could give rise to strong political opposition.

Another way to redirect soybean production to non-transjenic soybeans is to subsidize the production of non-transjenic soybeans. 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.

However 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 efficiency 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 certification (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.

The use of a quota market for the production of transgenic soybeans would make it possible to directly regulate production. It is a question of fixing the overall quantity of production and letting the companies choose the distribution of this production among themselves. In the end, the market selects the most efficient companies to produce. If, contrary to the tax, this instrument makes it possible to directly regulate the quantity of transgenic soybeans, the question of acceptability remains. From this point of view, the initial distribution of quotas can be used to achieve this objective, using a free distribution. Notably, following Montgomery (1974), whatever the quantity of quotas any producer initially receives, the final distribution of transgenic soybean production quotas among producers does not change. So 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. A free lump-sum allocation is a very appealing allocation rule 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 a free lump-sum allocation has two important shortcomings. First, this allocation rule does not contribute to the government fiscal revenue, contrary to an tax. Second, companies can try to manipulate environmental policy to their advantage. Indeed, the initial allocation of quotas may result in an imperfectly competitive quota market, depending on the relative bargaining power of producers. The purpose of this article is to explore this possibility, in order to propose the most appropriate policy to regulate transgenic soybean in Argentina.

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 and propose to implement it by a tradeable production quota market.

3.1 Assumptions and the "laissez-faire"

Consider n farms, each producing a quantity y_{1i} of transgenic soybean at a cost $C_1(y_{1i})$ and/or non-transgenic soybean y_{2i} at a cost $C_2(y_{2i})$, $\forall i = 1, \ldots n$. It is cheaper to produce transgenic soybeans than non-transgenic so we assume $C_1(y_{1i}) < C_2(y_{2i})$. Both cost functions are increasing and convex.[1] We assume that the international market determines a single competitive price, P, for transgenic and non-transgenic soybean.[2] We assume that in our short-term analysis, it is not possible to further extend agricultural land, and that global available land is limited to T. The production of y_{1i} and y_{2i} needs respectively a surface y_{1i} and y_{2i}. It will be assumed that the profitability of soybean production is such that all available land is used, such as $T = \sum_{i=1}^{n} (y_{1i} + y_{2i})$.

Let $D(\sum_{i=1}^{n} y_{1i})$ be the total damage caused by transgenic soybean production, with $D'(.) > 0$ and $D''(.) > 0$. In order to regulate transgenic soybean production, the regulator establishes a production quota market. He sets a production cap given by $\bar{Q}$ production quotas. For simplicity, each quota gives the right to produce one unit of transgenic soybean.[3] 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 can be freely issued or sold to farms in a primary market. Under free distribution, each farm receives $\bar{q}_i$ such that $\bar{Q} = \sum_{i=1}^{n} \bar{q}_i$. We assumed that this initial distribution is an exogenous one. Quotas can be exchanged on a secondary market at a price P_q.

We assume the "laissez faire" situation, i.e. no regulation on transgenic soybean production. A farm i chooses the optimal level of transgenic and non-transgenic soybean production that maximizes its profit, taking into account the constraint on available land T. We note λ the Lagrangian multiplier associated with the constraint. We have:

$$\boldsymbol{\Pi(y_{1i}, y_{2i}, \lambda) = P(y_{1i} + y_{2i}) - C_1(y_{1i}) - C_2(y_{2i}) - \lambda(\sum_{i=1}^{n} (y_{1i} + y_{2i}) - T)}$$

$$\boldsymbol{P - C_1'(y_{1i}^*) - \lambda^* = 0} \quad \textbf{(1)}$$

$$\boldsymbol{P - C_2'(y_{2i}^*) - \lambda^* = 0} \quad \textbf{(2)}$$

$$\boldsymbol{\sum_{i=1}^{n} (y_{1i}^* + y_{2i}^*) - T = 0} \quad \textbf{(3)}$$

Solving (1) and (2) yields:

$$\boldsymbol{C_1'(y_{1i}^*) = C_2'(y_{2i}^*)} \quad \textbf{(4)}$$

We consider a symmetric equilibrium such as $y_{1i} = y_1$ and $y_{2i} = y_2,$ $\forall i = 1, \ldots n$. Each producer chooses an optimal level of transgenic and non-transgenic production such that marginal costs of production are equal. As $C_1'(y_1^*) = [C_2'(T - y_1^*)]$, $y_1^* > y_2^*$ with $T/2 < ny_1^* < T$ (because $C_1'(y_1) < C_2'(y_2)$and $T = n(y_1^* + y_2^*)$, it follows that if the cost of producing non-transgenic soybean is much higher than that of transgenic soybean, the level of production of non-transgenic soybean will be very low. The early adoption of transgenic soybean observed in Argentina, triggered by its low cost of production, is a salient illustration of these theoretical predictions. However, this "laissez faire" situation does not take into account the environmental damage.

3.2 The first-best and a competitive market for production quota

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 farm profits but also the environmental damage induced by the production of transgenic soybean. As soybean production is mainly exported, the domestic consumer surplus is not taken into account in the welfare function. We consider a symmetric equilibrium. The welfare function can be written as follows:

$$\boldsymbol{W(y_{1i}, y_{2i,} \lambda) = nP(y_1 + y_2) - nC_1(y_1) - nC_2(y_2) - \beta(n(y_1 + y_2) - T) - D(ny_1)}$$

$$\boldsymbol{P - C_1'(y_1^{**}) - \beta^{**} - D'(ny_1^{**}) = 0} \quad \textbf{(5)}$$

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[1] We also assume a more technical condition $C_1'''(y_1) < 0$, ensuring a concave profit in Pq in Section 4.

[2] 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).

[3] We assume the penalty is sufficiently high to induce agricultural farms to comply with this policy.

$$\boldsymbol{P - C_2'(y_2^{**}) - \beta^{**} = 0} \quad \textbf{(6)}$$
$$\boldsymbol{n(y_1^{**} + y_2^{**}) - T = 0} \quad \textbf{(7)}$$

From (4) and (8), each level of production satisfies:

$$\boldsymbol{C_1'(y_1^{**}) + D'(ny_1^{**}) = C_2'(y_2^{**})} \quad \textbf{(8)}$$

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: $y_1^{**} < y_1^{*}$ and $y_2^{**} > y_2^{*}$. 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.

3.3 A regulation: A competitive tradable production quotas

Without regulation, the "laissez faire" situation does not reach the first-best outcome. If we compare Equations (1)-(2) with (4) and (8), it is easily to identify how to get the first best. The regulator can implement a tradable production quotas, such as $\bar{Q} = ny_1^{**}$. Including the requirement to hold production quotas to produce, the profit of farm i writes:

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

The first-order conditions are:

$$\boldsymbol{P - C_1'(y_{1i}^c) - \mu^c - P_q^c = 0} \quad \textbf{(9)}$$
$$\boldsymbol{P - C_2'(y_{2i}^c) - \mu^c = 0} \quad \textbf{(10)}$$
$$\boldsymbol{\textstyle\sum_{i=1}^{n} (y_{1i}^c + y_{2i}^c) - T = 0} \quad \textbf{(11)}$$

Solving (9) and (10) yields:

$$\boldsymbol{C_1'(y_{1i}^c) + P_q^c = C_2'(y_{2i}^c)} \quad \textbf{(12)}$$

As under competitive pollution quota market (Montgomery, 1972), the initial distribution of production quotas does not appear in Equations (9) and (10). This means that whatever the quantity of quotas any producer initially receives, the final distribution of transgenic soybean production among producers 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. Quotas can be issued without changing efficiency. As there is no role for initial distribution, we obtain a symmetric equilibrium such as $y_{1i}^c = y_1^c$ and $y_{2i}^c = y_2^c$. As farms can trade their quotas, the farm will buy (sell) quotas if the desired level of production exceeds (is inferior to) the allowances received, i.e., if $[y_1^c - \bar{q}_i] > 0$ (< 0). These exchanges on the secondary market set the price of the production quota P_q^c. Therefore, this competitive price of quotas creates appropriate incentives for farms to choose the "good" level of transgenic and non-transgenic soybean production: as $ny_2^c = T - ny_1^{**}$, we necessarily have $ny_2^c = ny_2^{**}$. 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 (12) shows that the level of production of 0transgenic (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.

4. An Imperfectly Competitive Transgenic Production Quota Market

In this section, we investigate the consequences of market power in the production quota market. To explore this idea, we assume that a group of firms, composed of $n - k$ firms, collude. This group of firms, the so-called cartel, acts as a single decision-making entity. This cartel may be formed by firms with the greatest market power in the soybean market, or by agrarian associations. Let us note this cartel by the subscript d. We want to analyze whether this cartel on the production quota market will just use its market power to minimize its compliance cost to soybean regulation or whether it will try to raise rivals' costs even if the soybean market is competitive.

4.1 The raising rival's cost strategy

The cartel will adopt a non-competitive behavior on the secondary market whereas k firms will act as a price-taker, i.e. representing the competitive fringe. In such a context, the cartel 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).

The second step

In this step, each farm chooses its level of production taking both prices (P_q and P) as given. The cartel maximize joint profits. As production decisions must be consistent with the quota market equilibrium, the cartel has to take into account this constraint in its profit. Let γ be the associated Lagrangian multiplier. Let's denote by $\bar{q}_d$ the sum of the initial allocations received by the cartel members. The cartel maximizes the following program:

$$\prod_d(y_{1d}, y_{2d}, \lambda, \gamma) = P(n-k)(y_{1d}+y_{2d}) - (n-k)C_1(y_{1d}) - (n-k)C_2(y_{2d}) - P_q((n-k)y_{1d} - \bar{q}_d)$$
$$-\mu((n-k)(y_{1d}+y_{2d}) + k(y_{1f}+y_{2f}) - T) - \gamma((n-k)y_{1d} + ky_{1f} - \bar{Q})$$

$$P - C_1'(y_{1d}^{nc}) - P_q^{nc} - \mu^{nc} - \gamma^{nc} = 0 \quad (13)$$

$$P - C_2'(y_{2d}^{nc}) - \mu^{nc} = 0 \quad (14)$$

$$(n-k)(y_{1d}+y_{2d}) + k(y_{1f}+y_{2f}) - T = 0 \quad (15)$$

$$(n-k)y_{1d} + ky_{1f} - \bar{Q} = 0 \quad (16)$$

The levels of production for the competitive fringe are given by Eqs. (9) and (10). Solving the system of Equations (13), (14), (15), (16), (9) and (10) (see Appendix) yields: $y_{2d}^{nc} = y_{2f}^{nc} = f(T, \bar{Q})$, $y_{1d}^{nc} = f(Pq, \bar{Q}, T)$, $y_{1f}^{nc} = f(Pq, \bar{Q}, T)$, $\lambda^{nc} = f(P, T, \bar{Q})$ and $\gamma^{nc} = f(Pq, \bar{Q}, T)$, with $\frac{\partial y_{1d}^{nc}}{\partial Pq} > 0$ and $\frac{\partial y_{1f}^{nc}}{\partial Pq} < 0$. As the production level of the cartel increases with the production quota price, we expect this farm to try to increase this price in order to expand its production level. It remains to find the value of Pq^{nc}.

The first step

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

$$\Pi_d(Pq, \bar{Q}, \bar{q}_d, P, T) \quad (17)$$

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

$$y_{1d}^{nc}(Pq, \bar{Q}, \bar{q}_d) - \bar{q}_d = \frac{\partial y_{1d}^{nc}(Pq, \bar{Q}, \bar{q}_d)}{\partial Pq}(P - C_1'(y_{1d}^{nc}(Pq, \bar{Q}, \bar{q}_d)) - P_q)$$

Eq. (17) shows that the optimal quota price is such that the net demand of quotas of the cartel equals the change in its marginal profit. Solving Equation (17), we obtain the manipulated quota price:

$$Pq^{nc} = f(\bar{Q}, \bar{q}_d, P, T) \text{ with } \frac{\partial Pq^{nc}}{\partial \bar{q}_d} > 0 \quad (18)$$

Two kinds of market manipulation are distinguished in the economic literature (Misiolek and Elder, 1989). If the cartel 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 in the output market by manipulating the quota price, it practices exclusionary manipulation. Equation (17) shows that the manipulated price takes into account not only the production quota market but also the output market. Thus the cartel 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.

Proposition 1- *Even if the product market is competitive, an organized group of farms can obtain an advantage into the product market using a strategic behavior on the production quota market.*

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 if the soybean 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 $\bar{q}_d$ is present in Eq. (18), 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.[4] Thus, the result obtained under the assumption of a competitive market of production quotas (Section 3.2) 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 that the cartel has no incentive to interfere on the production quota market, i.e., $\bar{q}'_d = y_{1d}^{nc}(Pq, \bar{Q}, T)$. The regulator grants the cartel a quota amount corresponding to its gain when it manipulates the quota market. From (17), it follows $P - C'_1 - P_q = 0$. But according to (9), $P - C'_1 - \lambda - P_q = 0$ 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 $\hat{q}_d$, such that:

$$\boldsymbol{\hat{q}_d / . P_q^{nc}(\bar{q}_d) = P_q^*}$$

Without this key initial distribution, the production quota market does not implement cost-efficiency. As $\frac{\partial Pq^{nc}}{\partial \bar{q}_d} > 0$, another way to limit this behavior is to auction quotas. When quotas are auctioned, the regulator raises revenue by issuing $\bar{Q} = ny_1^{**}$ production quotas. In this case, the initial quota distribution is null ($\bar{q}_d = 0$, $\forall i$), so each farm has to buy the right to produce transgenic soybean. 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 compensate for the fall in farms' profit resulting from the regulation, especially the most influential companies (Nicolai, 2019). We can also use this revenue to reduce exportation taxes on soybean. As the social cost of public funds is high in Argentina, that would improve the existing tax system, while obtaining the farms' support. Another solution to obtain cost-efficiency is to use an hybrid initial allocation. Production quotas can be grandfathered to the cartel with a specific initial allocation and auctioned to others. In each case, the initial distribution chosen will depend on the trade-off between efficiency, equity and acceptability of the environmental policy.

4.2 A numerical illustration

In order to better understand the effects of the cartel strategy, we use a numerical example. We set $n = 2$, $k = 1$, $P = 1$, $\bar{Q} = 1$, $T = 1.6$, $C_1(y_{1i}) = \frac{y_{1i}^2}{2}$, $C_2(y_{2i}) = y_{2i}^2$ and $\bar{q}_d = \alpha\bar{Q}$ with $\alpha \in [0; 1]$. Results are summarized in Figures 1 and 2:

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

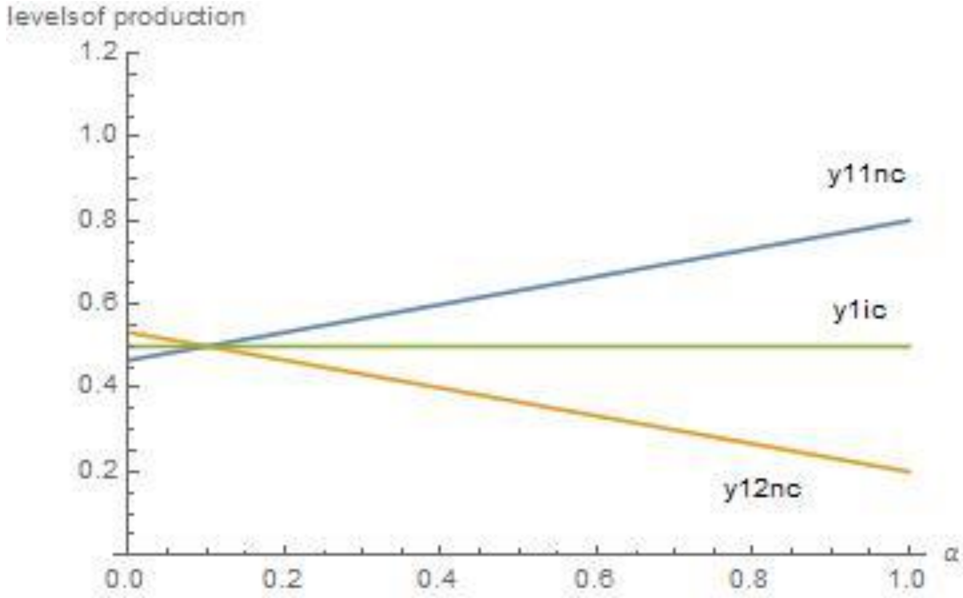

Figure 1 : Transgenic soybean production levels under perfectly and imperfectly competitive quota market

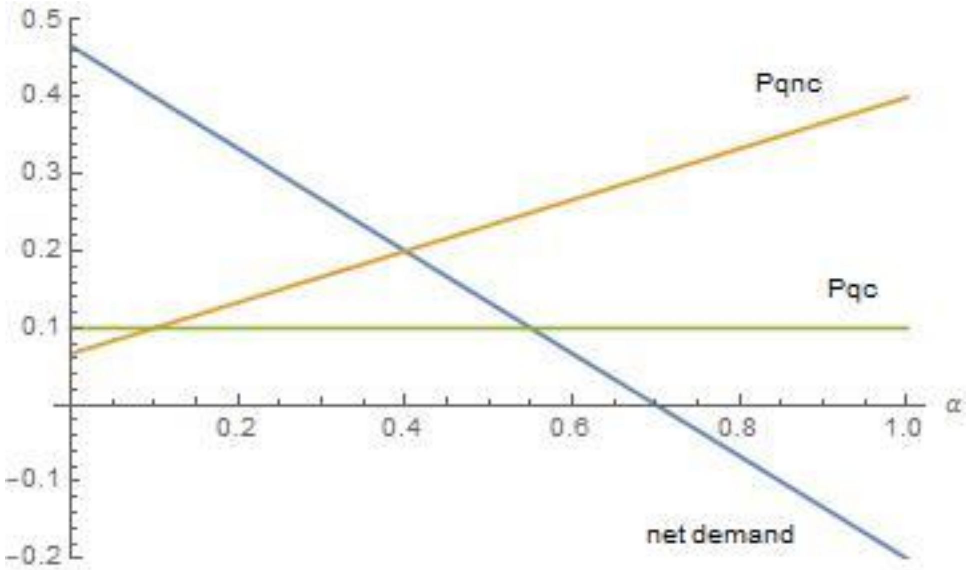

Figure 2 : Price variations and net demand of the dominant firm

The manipulated quota price (P_q^{nc}), the competitive quota price (P_q^c) and the net demand of the cartel given by $[y_{1d}^{nc} - \bar{q}_d]$ are represented in Figure 1 according to the initial allocation, denoted (α). Transgenic soybean production levels under competitive (y_{1i}^c) and non-competitive (y_{1i}^{nc}) quota market according to α are given in Figure 2. From these figures we can see that the cartel 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 cartel a higher share of the initial quota, he will push up the quota price as well as the cartel production level. If $\alpha = 0.7$ (corresponding to $\bar{q}_d'$), the cartel 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 cartel 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 (negative) if $\alpha < 0.7$ ($\alpha > 0.7$). 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 cartel is a buyer (seller), whereas the aim of exclusionary manipulation is always to increase it. If the cartel exerts monopoly power in the quota market, both manipulations lead to an increase in the quota price. If the cartel 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.

5. Conclusion

Transgenic soybean production has become one of the strategic components of Argentina's economy, and of the country's international positioning. However, transgenic soybean production induced numerous negative externalities such as deforestation, soil pollution and health problems resulting partly from the use of glyphosate. Considering 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. In order to give farmers flexibility, we propose, as a first step, to regulate the amount of transgenic soybean produced instead of banning it. The proposed regulation is based on output limitation instead of input application control. We first discussed the use of a tax on transgenic soybean production and a subsidy on non-transgenic production. Subsidize non-transgenic soybean is not a good idea, if we take into account the Argentinian debt level. An environmental tax would be inefficient to reduce the production of transgenic soybean, because of inelastic soybean supply.

We 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 efficiency and political acceptability. 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 cartel even if the soybean 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-efficiency. One way to limit this predatory strategy is to use the initial allocation of quotas in an adequate way.

At first sight, an auction could provoke a strong political opposition. But political opposition could be taken into account 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, especially the most influential companies. As the social cost of public funds is high in Argentina, it can also be used to reduce distortionary taxes, as exportation taxes on soybean. In this case, auction enables to obtain acceptability while improving the existing tax system. Another solution to obtain cost-efficiency is to use an hybrid initial allocation. Quotas can be grandfathered to cartel with a specific initial allocation and auctioned to others or grandfathered to others. In each case, the initial distribution chosen will depend on the trade-off between efficiency and acceptability of the environmental policy.

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. 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, it would be interesting to take into account the extent to which reducing Argentinian global soybean production would impact the world price of soybean.

6. Appendix

A competitive production quota market

From Eq. (9), (10), (11) and (12), we find:

$$y_2^c = \frac{T - \bar{Q}}{n}$$

$$\mu^c = P - C_2'(\frac{T - \bar{Q}}{n})$$

$$y_1^c = (C_1')^{-1}(-P_q^c + C_2'(\frac{T - \bar{Q}}{n})) = \frac{\bar{Q}}{n}$$

From (12), we set $F(y_1, y_2, P_q) = C_1'(y_1) + P_q - C_2'(y_2)$. Applying the Implicit Function Theorem, we find: $\frac{\partial y_1^c}{\partial P_q} = C_1''(y_1)^{-1} < 0$ and $\frac{\partial y_2^c}{\partial P_q} = C_2''(y_2)^{-1} > 0, \forall i$.

An imperfectly competitive quota market

(i) Determination of y_{1d}^{nc}, y_{1f}^{nc}, y_{2d}^{nc}, y_{2f}^{nc}

From (14), (15) and (16) we find:

$$\mu^c = \kappa^{nc} = P - C_2'(\frac{T-\bar{Q}}{n})$$

From (16), and using $y_{1f} = y_1^c$ we have:

$$y_{1d} = \frac{\bar{Q} - ky_{1f}}{(n-k)} = \frac{\bar{Q} - k[(C_1')^{-1}(-P_q + C_2'(\frac{T-\bar{Q}}{n}))]}{(n-k)} = f(Pq, \bar{Q}, T)$$

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

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

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

$$y_{21}^{nc} = y_{22}^{nc} = \frac{T-\bar{Q}}{n} = f(\bar{Q}, T)$$

(ii) The derivative of $\boldsymbol{\Pi_d(P_q)}$

$\Pi_d(P_q) = P(n-k)(y_{1d}(P_q, \bar{Q}, T) + y_{2d}(T, \bar{Q})) - (n-k)C_1(y_{1d}(P_q, \bar{Q}, T)) - (n-k)C_2(y_{2d}(T, \bar{Q})) - P_q((n-k)y_{1d}(P_q, \bar{Q}, T) - \bar{q}_d)$

$\frac{\partial \Pi_d(Pq)}{\partial Pq} = 0 \Leftrightarrow \frac{\partial y_{1d}}{\partial Pq} P - C_1' \frac{\partial y_{1d}}{\partial Pq} - [y_{1d} - \bar{q}_d] - P_q \frac{\partial y_{1d}}{\partial Pq} = 0$

(iii) $\boldsymbol{\Pi_d(P_q)}$ concave

$\frac{\partial^2 \Pi_1}{\partial Pq^2} = \frac{\partial^2 y_{1d}}{\partial Pq^2}(P - C_1' - P_q) - 2\frac{\partial y_{1d}}{\partial Pq} < 0$

(iv) The manipulated price

$P_q^{nc}(\bar{Q}, \bar{q}_d)$ is such $\frac{\partial \Pi_1}{\partial Pq} = 0$. Rearranging terms, we find Eq. (17).

(v) The variation of $\boldsymbol{P_q^{nc}(\bar{q}_d)}$ with respect to $\boldsymbol{\bar{q}_d}$

From Eq. (17), we set: $F(P_q, \bar{q}_d, \bar{Q}) = \frac{\partial y_{1d}(P_q, \bar{Q}, T)}{\partial P_q}[P - C_1' - P_q] - [y_{1d}(P_q, \bar{Q}, T) - \bar{q}_d]$. Applying the Implicit Function Theorem we obtain:

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

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