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The public management of price risk after a supply shock: storage vs. price floor

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Abstract

Exogenous shocks frequently have adverse effects on commodity markets. This article examines the fall of commodity price resulting from such shocks and explores strategies to manage these declines. Specifically, we compare two public management tools: a storage policy and the implementation of a price floor. To analyze these policies, we develop a tractable theoretical welfare model that we simulate. Using a case study of timber price drops following a storm, we demonstrate that a price floor is generally socially beneficial from a broader perspective but can be disadvantageous for consumer-taxpayers in the event of a storm of intermediate intensity. Additionally, our findings suggest that a storage policy is socially preferable in cases of low-intensity storms, whereas a price floor becomes more effective for higher-intensity events. Sensitivity analyses are conducted to assess the robustness of these results.

Keywords: risk, price, forest, policy, floor-price, storage, storm.

JEL classification numbers: D61 (Allocative Efficiency • Cost–Benefit Analysis); D81 (Criteria for Decision-Making under Risk and Uncertainty); Q23 (Forestry).

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1 Introduction

The principle of scarcity is the basis of microeconomics. It teaches us that the rarer a good is, the more expensive it is. Conversely, the more abundant a good becomes, the more its price falls. These price variations are often caused by an exogenous shock, and exogenous shocks are often due to weather shock as for commodities. For example, a year characterised by severe drought will generate low agricultural yields, leading to scarcity on the markets and higher prices. In the same way, pathogen attacks in forest lead to a large quantity of wood to be sold on the market and a fall in the price of wood.

These supply shocks have a significant impact on producers and consumers, particularly for commodities, and lead to price variations. It is easy to imagine the significant impact of an increase in a cereal price and its effect on the food, malnutrition, access to agricultural produce, etc. for the population. In the same way, the fall in timber prices represent a catastrophe for forest owners and State, with implications at various levels of the sector, from upstream to downstream.

Several tools are available to manage these price variations after a shock. For example, the public authorities can introduce price regulation. It is possible to set a floor price to prevent the price from falling too low, or a ceiling price to prevent the price from rising too high. Similarly, the public authorities can implement regulation on quantities with quotas, or set a storage policy to smooth market supply and reduce the price variation. In the context of climate change, climate shocks are expected to be more frequent and more intense, so the question of the public tools available to manage price risk after a supply shock becomes crucial.

In this paper, we address this question by focusing on the price fall of a commodity after an exogenous shock and we compare two public management tools, a storage policy and the setting of a price floor.[1]

In the literature, storage of commodities has been analysed theoretically by Deaton and Laroque (1992) and Newberry (1989). The first one applies the standard rational expectations competitive storage model to the study of thirteen commodities. The results show that for most of studied commodity prices, the behaviour of prices from one year to the next conforms to the predictions of the theory about conditional expectations and

[1]Note that price volatility of the commodities is not the scope of this paper since they are generally manage through supply contract.

conditional variances. Newberry (1989) proposed a simple analytical framework to study the imbalance in theoretical understanding of producer and consumer price instability. The results indicate that if consumers find it more costly to store than commercial agents, then, from the consumers' viewpoint, the competitive market undertakes too little storage. These two first papers provide interesting insight on the way to model storage from the point of view of various actors. Storage was also studied in more specific context like forestry by Costa and Ibanez (2005), Caurla et al. (2015) and Jacob et al. (2024). Costa and Ibanez (2005) provided a cost-benefit analysis of the storage policy implemented after the windstorms of 1999 in France. The authors indicated that, from the point of view of the forest owners, the storage was not profitable, and for the public authority, the overall balance is not positive too since 85% of created storage area had negative outcomes. Caurla et al. (2015) assessed the economic impacts of the public help implemented by French government after Klaus in 2009 on the forest sector. They show that the global impact was beneficial, in-site storage and export abroad were favored, as compared to a situation without a plan, which favored direct consumption. In addition, the price decrease after Klaus was reduced when the storage proportion increases. Jacob et al. (2024) proposed a tractable theoretical model which assesses welfare losses and gains incurred/earned by all agents of the society (supply, consumers and the public agent), from the storage after a storm in forestry. The results show that globally, the storage policy is always desirable except for the consumers in the case of storms associated with a low magnitude.

In agricultural economics, we found reference to a price floor policy behind the deficiency payment program implemented in some countries like U.S (Miranda and Glauber, 1991) and Canada (Martin and MacLaren, 1976). The objective was to provide improved income protection in the event of widespread crop failure. Indeed, the farmers perceived a payment based on the difference between a target price and the market price. Most of the literature on the topic proposes improvement of the existing scheme. Miranda and Glauber (1991) proposed that the producer's payment would be based on the difference between a target revenue and the average revenue in the producer's region. Gardner (1988) shows that a combination of direct producer payments (like in the deficiency payment program) and consumption taxes is preferable to an export subsidy. Adams et al. (2000) assess the impacts of a reduced government deficiency payments for wheat producers. They show that the deficiency payment program was no better than other hedging strategies (delayed sales using storage, purchase of futures and options contracts) in reducing post-harvest risk. The idea of the deficiency payment is close to ours, avoiding the price to drop too low in case of exogenous shocks in the market, and we propose to apply it to our problematic.

This short overview lets appeared that there is no comparison of tools in the literature allowing to manage a price fall following a shock. That is what we propose to do in this article. One originality is to adopt two different points of view, the commodity's owner and a social planner who takes into account both the interests of the owner and of all the downstream agents/sector. We propose to address this research question based on a case study: timber price decrease consecutive to a supply shock after a storm occurrence. For that purpose, we develop a theoretical microeconomics model of the price floor policy. In addition, we compared this price floor policy to the storage policy modelled in Jacob et al. (2024). We provide empirical evidence through simulations. We show that a price floor policy is always socially desirable. In addition, our results indicate that a storage policy is socially preferred to a price floor policy in case of storm of low magnitude, otherwise a price floor policy is preferred. The intensity of the storm is thus detrimental in terms of social desirability of the public policy.

The rest of the paper is structured as follows. Section 2 describes the case study we focus on. Section 3 presents the microeconomics model of the price floor policy. Section 4 presents the results of the simulations. Section 5 discusses the implications of the results and concludes.

2 Case study

We decide to consider a case study to analyse the question of the comparison of public policies to face a supply shock generating a price fall. In particular, we focus on the price decrease due to a high quantity of timber on the market after a storm. Indeed, a supply shock is very common following a storm occurrence in the forest sector. Following windstorm Gudrun, the average prices of sawlogs of spruce and pine in Sweden was only 63% and 86%, respectively, of those in the year before the storm (Gardiner et al., 2011). After windstorm Klaus, 50% of the windfalls suffered from a depreciation due to a price decrease on the timber market (Nicolas, 2009). Hurricane Hugo in U.S in 1989 was another example, damaging 20% of the southern pine on the South Carolina Coastal Plain. Modelling revealed a 30% negative price spike due to salvage (Prestemon and Holmes, 2000). When a storm occurs, the timber market becomes dual since two types of wood coexist, the wood of low quality due to the damage of the storm and the wood of good quality not impacted by the storm (Brunette et al., 2015).

In order to try to cope with this price decrease after storm occurrence, a classical option for governments is to facilitate wood storage. After Lothar and Martin, Germany provided a public help of €15.3 millions for windfall hauling, transportation, storage and replanting (Holecy and Hanewinkel, 2006), whereas French government implemented a 10-years program providing €920 millions with the objective to remove windfall timber, to clear and replant, and to create storage areas for harvested timber (CGAAER, 2010). After Klaus, the French government dedicated €25 millions to the creation of storage area (Bavard et al., 2013).

Given this context, we decide to enlarge the possible options existing to manage such a price fall to a price floor policy. Our objective is to compare the price floor with a storage policy, as modeled in Jacob et al. (2024), from the point of view of the foresters, the consumers and the public authority.

3 Model

We present the setting of the model and then we model the price floor policy. Finally, we will briefly recall what happens in the context of *laissez-faire* and storage policy.

3.1 Setting

The setting of the model is similar to the one developed in Jacob et al. (2024). We consider a representative risk-neutral forester aiming at maximizing its own expected profit. This forester is in a monopoly position, and faces the whole demand for wood. Only one species of wood exists. The forester can harvest standing wood, which is considered as being wood of high quality. In addition, in case of a storm occurring, a quantity Q of wood falls on the ground. This quantity, denoted by Q, is windfall, and we assume that this windfall is a wood of lower quality than the standing wood which is harvested. As a consequence, in case of a storm, the market of wood becomes dual: the harvested standing wood (high quality), and the windfall (low quality).

We consider 3 periods: in a first period (period 0), the forester decides a first quantity of standing wood to harvest. This quantity is QR_0. We consider that there is a lag in time between the harvesting period, and the time where the wood is sold: the cost of harvesting QR_0 is incurred in period 0, while the benefit from selling QR_0 is earned in the next period, period 1.

However, in period 1, a storm may occur (with a probability p). In that case, there is a quantity Q of windfall. As regards windfall, since the quality of wood deteriorates very quickly, the forester has to sell it at the period of storm: so, in period 1, both the longshoring cost of the windfall is incurred and the benefit from selling it is earned. Moreover, still in period 1, the forester has the possibility to harvest another quantity of standing wood and, again, the cost is incurred in period 1 but the benefit from selling is earned in the next period, period 2. This harvested quantity in period 1 (while a storm occurred) is denoted QR_1^H. In the case where no storm has occurred (probability $(1-p)$), only harvested wood is present on the market. The quantity of harvested wood in period 1 when no storm occurred is denoted QR_1^{NH}.[2]

In period 2, the forester earns the benefit from selling the standing wood that was harvested during period 1 (see the expression of forester's profit later).

This setup can be represented by the decision tree in Figure 1 where F stands for "Forester" and N stands for "Nature". There is no discount factor, and we consider no capacity constraint as regards the ability to harvest.

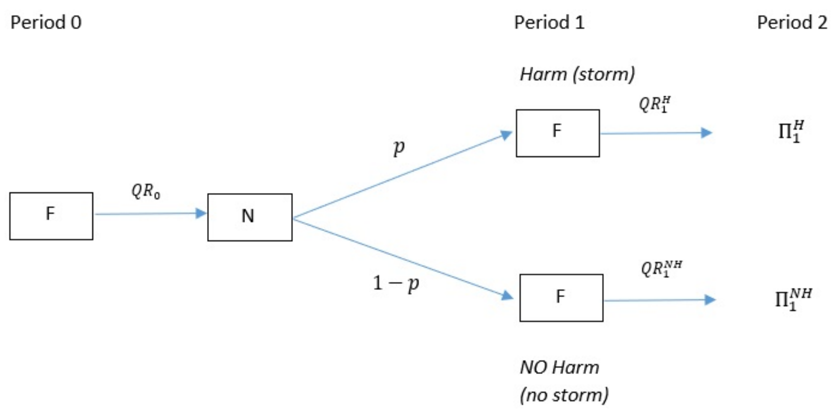

Figure 1: Decision tree

Let $\overline{k}$ be the unit cost of harvesting standing wood, and $\underline{k}$ be the unit cost of long-

[2]The superscript H stands for "harm" and denotes the state of Nature where storm occurs. The superscript NH (no harm) refers to the state of Nature where no storm occurs.

shoring windfall. Hence, the total cost of harvesting QR_0 in period 0 is $\overline{k}QR_0$, and the total cost of longshoring Q in period 1 in case of storm is $\underline{k}Q$. For a given quantity of wood, the cost of longshoring windfall is higher than the cost of harvesting standing wood: $\underline{k} > \overline{k}$. Indeed, it is more complicated and it takes more time and workforce to evacuate wood after a windstorm than harvesting wood as usual.

When a storm occurs, the market becomes dual: both wood of high quality (harvested standing wood) and wood of low quality (windfall) are present on the market. For a given quantity of wood, we suppose that the consumers' willingness to pay for the wood of high quality is higher than for the wood of low quality. However, both kinds of wood are imperfect substitutes. As a result, the demand functions of the high and low quality woods are as follows.

First, consider the case where no storm occurred. Only high quality harvested standing wood is available on the market. The demand for that wood of high quality (indexed by $\overline{Q}$), for a given quantity QR of harvested standing wood is:

$$P_{\overline{Q}}(QR) = \alpha_R - \beta_R QR.$$

In the case where a storm occurred in period 1, the market becomes dual: high quality standing wood and low quality windfall coexist (and are imperfect substitutes). In that case, the demand for wood of high quality (indexed by $\overline{Q}$), for a given quantity QR of harvested standing wood, and a given quantity of windfall Q, is:

$$P_{\overline{Q}}(QR, Q) = \alpha_R - \beta_R QR - \delta Q.$$

The demand for wood of low quality (indexed by $\underline{Q}$), for a given quantity QR of harvested standing wood, and a given quantity of windfall Q is:

$$P_{\underline{Q}}(Q, QR) = \alpha - \beta Q - \delta QR.$$

Our assumptions about demand lead to: $\alpha_R > \alpha > 0$, $0 < \beta_R < \beta$. δ is a parameter that takes into account for the imperfect substitution between the two kinds of wood, with $0 < \delta < 1$.[3]

[3]These demand functions are inverse demand functions, providing the maximum willingness to pay for a given quantity of wood.

3.2 price floor policy

We first introduce this policy, and how the private forester reacts to it. Then we present the social welfare induced by the implementation of that policy.

3.2.1 Private decisions

In the case of a price floor policy, in period 1, in case of storm, if the market price of wood falls below a floor, then the public agent pays a subsidy to the forester which amounts, for each sold quantity, to the difference between the floor and the market price. As a result, consumers still buy wood at the (low) market price, but the forester earns, for each sold quantity, the minimum price floor, fixed by the public agent.[4] The taxpayer is thus helping the forester to maintain her revenues when the market price falls below a given floor. We suppose that using public funds is costly: λ (with $\lambda > 0$) is a factor cost of using public funds (see later). So in period 1, in case of storm, two price floors can be triggered, one for each quality of wood. We define: $\overline{P}_{min}$ the price floor for the wood of high quality, and $\underline{P}_{min}$ the price floor for the wood of low quality.

Even in the case where there is a public intervention onto the market in case of storm, decisions are made by a private agent, the forester, who aims at maximizing its own expected profit. The model is solved backward.

First, consider the profit from period 1 (which integrates the earnings from period 2), when there is no storm. In that case, the forester has to maximize:

$$\begin{aligned}\Pi_1^{NH}\left(QR_1^{NH}, QR_0\right) &= P_{\overline{Q}}(QR_0)QR_0 - \overline{k}QR_1^{NH} + P_{\overline{Q}}\left(QR_1^{NH}\right)QR_1^{NH} \\ &= (\alpha_R - \beta_R QR_0)QR_0 - \overline{k}QR_1^{NH} + \left(\alpha_R - \beta_R QR_1^{NH}\right)QR_1^{NH}, \quad (1)\end{aligned}$$

with QR_0 the quantity of harvested wood decided in period 0. The resulting optimal quantity QR_1^{NH*} is:

$$QR_1^{NH*} = \frac{\alpha_R - \overline{k}}{2\beta_R}.$$

In case of storm in period 1, the four following cases may happen, depending on which price floor is reached, or not:

[4] In this section, to ease the exposition of the model, we assume that the market price remains strictly positive. For the case of a market price falling to zero, see Appendix A.1. Such a possibility will be taken into account in our numerical analysis (see Section 4).

- Case 1: no price floor is triggered. This is the case if these two conditions are both satisfied: $P_{\overline{Q}}(QR_0, Q) \geq \overline{P}_{min}$ and $P_{\underline{Q}}(Q, QR_0) \geq \underline{P}_{min}$.
- Case 2: both price floors are triggered. This is the case if these two conditions are both satisfied: $P_{\overline{Q}}(QR_0, Q) < \overline{P}_{min}$ and $P_{\underline{Q}}(Q, QR_0) < \underline{P}_{min}$.
- Case 3: only the price floor on high quality is triggered. This is the case if these two conditions are both satisfied: $P_{\overline{Q}}(QR_0, Q) < \overline{P}_{min}$ and $P_{\underline{Q}}(Q, QR_0) \geq \underline{P}_{min}$.
- Case 4: only the price floor on low quality is triggered. This is the case if these two conditions are both satisfied: $P_{\overline{Q}}(QR_0, Q) \geq \overline{P}_{min}$ and $P_{\underline{Q}}(Q, QR_0) < \underline{P}_{min}$.

We can remark that triggering a price floor can both be exogenous, or endogenous, to the forester's decision. Indeed, a price floor is triggered as soon as the market price falls below the floor. Knowing that both $P_{\overline{Q}}(QR_0, Q)$ and $P_{\underline{Q}}(Q, QR_0)$ are decreasing with the quantity of windfall Q, it could be possible that one or both floors to be triggered because of a high quantity of windfall Q has fallen on the ground (storm of high intensity), whatever the decision about QR_0. But it could also be possible that, for the given quantity Q, no floor is reached but, by increasing the quantity QR_0, the market price falls in a way to trigger one or both price floors. As such, the forester can choose in which of these four cases she would be in case of storm. This possibility for strategic triggering of floors will be taken into account in our numerical simulations (in Section 4).[5]

In period 1, in case of storm, the profit that the forester has to maximize is:

$$\begin{aligned} \Pi_1^H\left(QR_1^H, QR_0\right) &= \max\left\{P_{\overline{Q}}(QR_0, Q), \overline{P}_{min}\right\} QR_0 - \overline{k} QR_1^H \\ &+ \max\left\{P_{\underline{Q}}(Q, QR_0), \underline{P}_{min}\right\} Q - \underline{k} Q + P_{\overline{Q}}\left(QR_1^H\right) QR_1^H. \end{aligned}$$

Recall that price floors only apply (potentially) in period 1, so that only the earnings from selling QR_0 or Q may benefit from this policy. The earning from selling QR_1^H, which occurs in period 2, is not concerned by the policy.

[5] Increasing QR_0 (in a way to trigger a price floor) makes possible to the forester to sell a high quantity of wood at a non-decreasing marginal earning. Such a strategy could be valuable in case of a high likely storm, of a high magnitude (from the moment that consumers still have a positive willingness to pay for these additional quantities of wood).

The optimal quantity harvested in period 1, QR_1^{H*}, satisfies:

$$\frac{\partial \Pi_1^H \left(QR_1^H, QR_0\right)}{\partial QR_1^H} = 0 \Rightarrow QR_1^{H*} = \frac{\alpha_R - \overline{k}}{2\beta_R}.$$

The decision about QR_1^H is independent from the price floors, so that QR_1^H can easily be determined. Moreover, we remark that QR_1^H is equal to QR_1^{NH} since both the cost and benefit from harvesting in period 1 are not altered by the policy or the occurrence of the storm.[6]

The optimal value of QR_0 aims at maximizing:

$$E[\Pi_0(QR_0)] = -\overline{k}QR_0 + p\Pi_1^H \left(QR_1^{H*}, QR_0\right) + (1-p)\Pi_1^{NH} \left(QR_1^{NH*}, QR_0\right). \quad (2)$$

Under a policy of price floors, there is an interaction between QR_0 and the trigger of price floors: depending on the value of QR_0, price floors can be triggered which, by feedback, has an impact on the optimal value of QR_0. Four cases leads to four different values of $\Pi_1^H \left(QR_1^{H*}, QR_0\right)$, and four different optimal values for QR_0.

In Case 1 (no price floor is triggered), the optimal value QR_{0-1}^* is:

$$QR_{0-1}^* = \frac{\alpha_R - 2p\delta Q - \overline{k}}{2\beta_R}.$$

In Case 2 (both price floors are triggered), the optimal value QR_{0-2}^* is:

$$QR_{0-2}^* = \frac{(1-p)\alpha_R + p\overline{P}_{min} - \overline{k}}{(1-p)2\beta_R}.$$

In Case 3 (the price floor on high quality is triggered), the optimal value QR_{0-3}^* is:

$$QR_{0-3}^* = \frac{(1-p)\alpha_R + p\left[\overline{P}_{min} - \delta Q\right] - \overline{k}}{(1-p)2\beta_R}.$$

In Case 4 (the price floor on low quality is triggered), the optimal value QR_{0-4}^* is:

$$QR_{0-4}^* = \frac{\alpha_R + p\delta Q - \overline{k}}{2\beta_R}.$$

[6] As regards the benefits from selling QR_1^H in period 2, since all the windfall Q are sold in period 1, there is no interaction between high and low qualities of wood in period 2.

Details about calculations are available in Appendix A.2.

Once these four values are determined, the forester chooses the value (and the associated case) which maximizes its expected profit $E[\Pi_0(QR_0)]$, among the existing cases.[7]

3.2.2 Social welfare

We will now calculate the social welfare that derives from implementing a price floor policy. The social welfare is the sum of benefits and costs that take part in this economy, from all parties: the consumers' surplus, the expected profit of the forester, and the cost of using public funds (public agent).

A social cost of using public funds appears only in cases where price floors are triggered. As regards the consumers, they benefit from a surplus[8] which is based on the market price, even if a price floor is triggered.[9] Finally, recall that four different equilibria can be reached (they are mutually exclusive), depending on which case will be chosen by the forester as regards the triggering of price floors. As a result, there are also four possible cases as regards the social welfare.

In Case 1 (no price floor is triggered), the expected social welfare is:

$$\begin{aligned} SW\left(QR_{0-1}^{*}, QR_1^{H*}, QR_1^{NH*}\right) &= E[\Pi_0(QR_{0-1}^{*})] + \frac{1}{2}\beta_R(QR_{0-1}^{*})^2 + p\frac{1}{2}\beta_R\left(QR_1^{H*}\right)^2 \\ &+ (1-p)\frac{1}{2}\beta_R\left(QR_1^{NH*}\right)^2, \end{aligned}$$

which is the sum of the forester's expected profit, and the three consumers' surplus enjoyed from the consumption of QR_{0-1}^{*}, QR_1^{H*} (when a storm occurs) and QR_1^{NH*} (when no storm occurs), respectively. In that case, there is no cost of using public funds, since price floor are not triggered (no subsidy is paid).

[7]Indeed, from a theoretical point of view, the four cases we describe above may exist. But from a practical point of view, if, for instance, the value of windfall Q is very large then, before making any decision about QR_0, the first case can be non available. Such a situation arrives because a price floor , say $\underline{P}_{min}$, is already triggered even for $QR_0 = 0$. In that situation, the external context prevents the forester to reach the first case. As a consequence, among the *available* cases (that can be reached), the forester chooses the one which maximizes its expected profit.

[8]Details about the calculation of the consumers' surplus in our setup are provided in Jacob et al. (2024), Appendix A.1.

[9]Recall that price floors act as a subsidy from the public agent to the forester: consumers still buy the wood at the market price, but if that market price falls below the price floor then the public agent subsidize the forester "as if" the forester sells the wood at that guaranteed price.

In Case 2 (both price floors are triggered), the expected social welfare is:

$$
\begin{aligned}
SW\left(QR_{0-2}^*, QR_1^{H*}, QR_1^{NH*}\right) = E[\Pi_0(QR_{0-2}^*)] + \frac{1}{2}\beta_R(QR_{0-2}^*)^2 + p\frac{1}{2}\beta_R\left(QR_1^{H*}\right)^2 \\
+(1-p)\frac{1}{2}\beta_R\left(QR_1^{NH*}\right)^2 \\
-p(1+\lambda)\left[(\overline{P}_{min} - P_{\overline{Q}}(QR_0, Q))QR_{0-2}^* + (\underline{P}_{min} - P_{\underline{Q}}(Q, QR_0))Q\right],
\end{aligned}
$$

with the last term representing the cost of using public funds, in case of storm, to provide subsidies to the forester for the two qualities of wood. $\lambda > 0$ is a factor cost of using public funds: providing a subsidy of 1 costs $(1 + \lambda > 0)$ because of administrative costs.

In Case 3 (the price floor on high quality is triggered), the expected social welfare is:

$$
\begin{aligned}
SW\left(QR_{0-3}^*, QR_1^{H*}, QR_1^{NH*}\right) &= E[\Pi_0(QR_{0-3}^*)] + \frac{1}{2}\beta_R(QR_{0-3}^*)^2 + p\frac{1}{2}\beta_R\left(QR_1^{H*}\right)^2 \\
&+ (1-p)\frac{1}{2}\beta_R\left(QR_1^{NH*}\right)^2 \\
&- p(1+\lambda)(\overline{P}_{min} - P_{\overline{Q}}(QR_0, Q))QR_{0-3}^*.
\end{aligned}
$$

In Case 4 (the price floor on low quality is triggered), the expected social welfare is:

$$
\begin{aligned}
SW\left(QR_{0-4}^*, QR_1^{H*}, QR_1^{NH*}\right) &= E[\Pi_0(QR_{0-4}^*)] + \frac{1}{2}\beta_R(QR_{0-4}^*)^2 + p\frac{1}{2}\beta_R\left(QR_1^{H*}\right)^2 \\
&+ (1-p)\frac{1}{2}\beta_R\left(QR_1^{NH*}\right)^2 \\
&- p(1+\lambda)(\underline{P}_{min} - P_{\underline{Q}}(Q, QR_0))Q. \qquad (3)
\end{aligned}
$$

3.3 Other policies: *laissez-faire* and storage

In order to see whether it is socially desirable to implement a price floor policy in case of storm occurrence, it is necessary to compare the price floor policy to a policy of *laissez-faire*, i.e., the absence of policy.

Furthermore, as mentioned in the Introduction, policies typically implemented following a storm are storage policies. A comprehensive analysis thus requires to analyze both the desirability of the price floor policy (compared to *laissez-faire*), but also to analyze how it performs relatively to its main alternative, namely a storage policy.

Both *laissez-faire* and storage policies, developed in the same setup that the one introduced in the paper at hand, have been introduced and analyzed in Jacob et al. (2024). In that case, storage consists in making storage areas which make possible for the forester to store windfall (fallen on the ground in period 1, in case of storm) and to sell it in period 2 (instead of being forced to sell all windfall Q in period 1). Storage makes possible to smooth the shock of windfall over two periods. We invite the reader to refer to Jacob et al. (2024), sections 2.2 and 2.3 to discover these two policies of *laissez-faire* and storage, and section 3 to see a comparative analysis.

In the next section, we make two comparative analyses. First, we analyze the social desirability of price floor by comparing it to a policy of *laissez-faire*, and then we make a comprehensive analysis comparing *laissez-faire*, price floor and storage. Since the theoretical model can not be solved analytically, we ran numerical simulations that aim at realizing these comparisons.

4 Results

Because the analytical resolution of the relatively complex model was not reached, we use a more tractable way, namely simulations, to look at implications of all policies for the forester, the consumer and the whole social welfare. The value of the different parameters used to calibrate the model is presented in the following table.

Table 1: Values of the parameters for the simulations (benchmark scenario).

Parameter	Description	Values	Assumptions
$\bar{k}$	Unit cost of harvesting standing wood	1	
$\underline{k}$	Unit cost of longshoring windfall	1.5	$\underline{k} > \bar{k}$
k_s	Unit costs of storing	1.3	
$\bar{P}min$	Price floor - Wood of high quality	500	
$\underline{P}min$	Price floor - Wood of low quality	300	$\bar{P}min > \underline{P}min$
λ	Cost of using public funds	1.2	$\lambda > 0$
δ	Degree of substitution between the two kinds of wood	.1	$0 < \delta < 1$
β_R	Price-elasticity of demand - Wood of high quality	.4	
β	Price-elasticity of demand - Wood of low quality	.8	$\beta_R < \beta$
α_R	Ordinate of the demand function - Wood of high quality	2000	
α	Ordinate of the demand function - Wood of low quality	1600	$\alpha_R > \alpha$

Given these values, in the case where no storm occurs, we obtain: $QR_1^{NH*} = 2498.75$, which can be seen as the value of an average harvest of one period in a normal situation. As a consequence, in the following simulations a storm of magnitude $Q = 5000$ could be seen as a storm for which the windfall is equivalent to 2 periods of harvest in a normal situation. As an example, in France, the forest damage due to storms Lothar and Martin in 1999 correspond roughly to three years of harvesting (IFN, 2003).

It is important to note that without any public policy (*laissez-faire*), only the producer and the consumer are present in the economy: they share the social welfare. But in case of implementing a policy, either storage or price floor, a third agent is present, the public regulator, who bears the cost of implementing the public policy.

4.1 Price floor: comparison with *laissez-faire* (no policy)

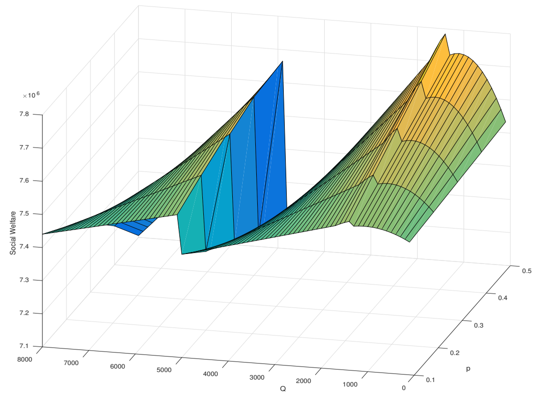

Figure 2: Social welfare in the case of price floor policy.

In Figure 2, we can see the three cases which can occur depending on the magnitude of the storm: given our calibration parameters, for $p = 0.2$, when $Q < 1320$ case 1 occurs (no price floor is triggered) and the situation is similar as a *laissez-faire* (no policy, the market is free), when $1320 < Q < 4980$ the case 4 occurs (floor triggered in the windfall market only), and when $Q > 4980$ the case 2 occurs (both floors are triggered). We can see that for low magnitudes of storm (case 1), an increase in the magnitude is socially desirable, since there is a demand for windfall and the decrease in prices benefits to the consumers. Then, conditional to each two other cases, an increase in the magnitude of storm decreases the whole social welfare. However, the reasons explaining why the social welfare decreases with Q differ among the case. In case 4 (i.e., $1320 < Q < 4980$ for $p = 0.2$), when only the floor on windfall is triggered, an increase in Q leads to a decrease in the demand for harvesting wood (because of the substitution between both qualities of wood δ). In reaction, the forester restricts the quantity of harvested wood QR_0, in the aim to slow the fall in price. So, in that case, both the profit (because the fall in price of harvested wood) and the consumer surplus (because of the decrease in the available quantities of harvested wood) decrease in Q, explaining the decrease in social welfare (see Figures 17 and 18 in Appendix C). As regards what happens in case 2 (i.e., $Q > 4980$

for $p = 0.2$), when both price floors are triggered, the explanation is different. Here, the decrease in social welfare with Q is only due to the increase in the cost of implementing the price floor policy. Given that the market for windfall is saturated (floor is triggered, and the selling-price for consumers is fallen to zero) and the floor for harvested wood is triggered, all markets are "frozen": consumers and forester don't change their decisions. However, the selling price of harvested wood for consumers continue to decrease, leading to an increase in the subsidy to the forester (in order to keep her revenue equal to the floor $\bar{P}_{min}$). The forester's profit and the consumers' surplus are (quite) constant, but the rise in the policy cost leads the social welfare to decrease in Q.

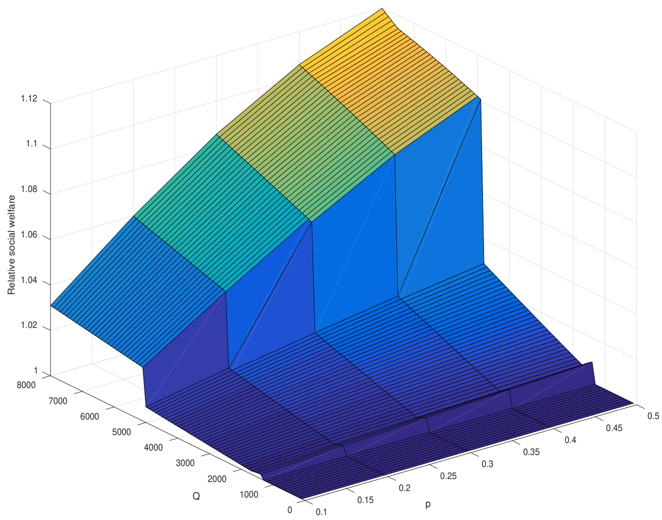

Figure 3: Social welfare in the case of price floor policy, relative to *laissez-faire*.

In Figure 3 we can observe that, globally, a policy of price floor is always socially desirable: the ratio between the social welfare reached under a price floor policy and a *laissez-faire* policy (no policy) is always higher than 1 (see the axis "Relative social welfare"). Moreover, the relative desirability of the policy increases with the magnitude of storm: even if the social welfare under a price floor policy is, globally, decreasing with the magnitude Q of storm, this decrease in social welfare is lower than those which prevails when no policy is implemented (see Jacob et al. (2024), section 3.1.).

Figures 4 and 5 shows that, relatively to a situation of *laissez-faire* (no policy), both the consumers and the foresters are better off in the case of a price floor policy. As

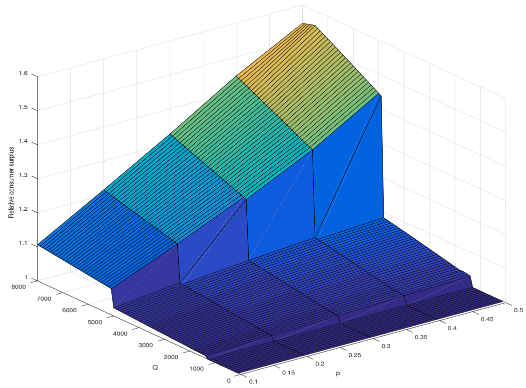

Figure 4: Consumer surplus in the case of price floor policy, relative to *laissez-faire*.

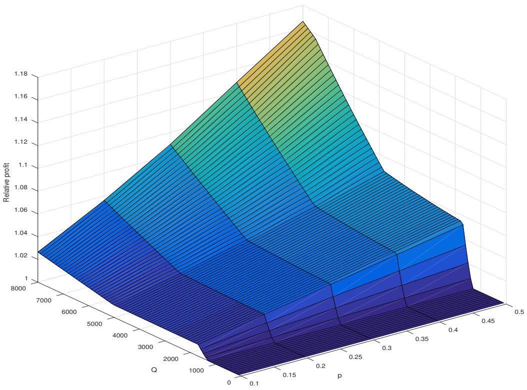

Figure 5: Profit in the case of price floor policy, relative to *laissez-faire*.

regards the consumers, this is explained by the fact that the floors, which stopped the fall in prices for the forester,[10] lead the forester to less restrict the quantity of harvested wood QR_0 she offers.[11] More precisely, in case 4 (i.e., $1320 < Q < 4980$ for $p = 0.2$), when only the floor on windfall is triggered, the presence of the price floor leads the forester to restrict the quantity of wood QR_0 to a lesser extent than when no policy is implemented. And in case 2 (i.e., $Q > 4980$ for $p = 0.2$), when both price floors are triggered, the forester no longer restricts the quantity QR_0 at all when Q increases. To sum up, it is the greater overall supply, at moderate prices, which makes the consumers

[10] Recall that the consumers always pay the market price: if that market price falls below the floor, the regulator pays a subsidy to the forester (which ensures her to earn the floor).

[11] In Jacob et al. (2024) section 3.1, where the situation of *laissez-faire* is developed, we show that an increase in the magnitude Q of storm leads the forester, in anticipation, to decrease the quantity of harvested wood QR_0 in period 0 in the aim of keeping a high level of price for that kind of wood: this leads to a reduction in consumers' surplus.

better-off in case of a price floor policy (relatively to *laissez-faire*). The difference in supply in wood between the price floor policy and the *laissez-faire* increases with the magnitude of storm, which explains why the relative gain for consumers increases in Q. As regards the forester's profit, relatively to a situation of *laissez-faire*, the subsidies make her possible to maintain her level of profit while in case of *laissez-faire* her profit is always decreasing in Q.

According to Figure 4, consumers seem to be the winner of that price floor policy, and in a wider extent than the forester. However, as we highlighted above, the cost of implementing such a policy can be high in case of storms of high magnitude. Until now, we assumed that the cost of the public policy is incurred by a third agent, the public agent. This being said, in reality, the public agent raises its funding through taxes, which ultimately are borne by the consumers. In the event that the consumers are also the taxpayers who have to finance this policy, would that policy still be desirable for them?

The Figure 6 allows us to answer to this question. Indeed, it is, in spirit, similar to Figure 4: it highlights the ratio between the consumers' surplus in case of implementing a price floor policy, and the consumers' surplus in case of a *laissez-faire*. However, contrary to the situation depicted by Figure 4, in Figure 6 the cost of the price floor policy is not borne by a third (public) agent anymore. Here, we assume the cost of policy to be borne by the consumers, in case of a storm. We can see that, for a probability $p = 0.2$, in case of storms of a magnitude lying between $Q = 1450$ and $Q = 4980$,[12] the consumers-taxpayers are losers if they have to finance the policy of price floor. More precisely, for that range of values of Q, the price floor on windfall is triggered. Comparatively to the case of *laissez-faire*, in case of price floor the forester offers a higher quantity of harvested wood QR_0, which leads to an increase in the consumers' surplus. But this positive effect on welfare is completely offset by the cost of subsidies paid to the forester, in a way that the consumers' surplus net of the cost of policy is lower than the consumers' surplus prevailing in case of *laissez-faire*. Then, for storms of magnitudes Q higher than 4980, the two price floors are triggered and the increase in the offering quantity of harvested wood QR_0 (relatively to *laissez-faire*) leads to an increase in the consumers' surplus that

[12]Recall that an harvest during one period in a normal situation is equal to 2498.75. So, a storm of a magnitude $Q = 1450$ is equivalent to 0.6 harvest, and a storm of a magnitude of $Q = 4980$ is equivalent to two periods of harvest.

is higher than the cost of the policy, so that the policy is improving even for "consumers-taxpayers".

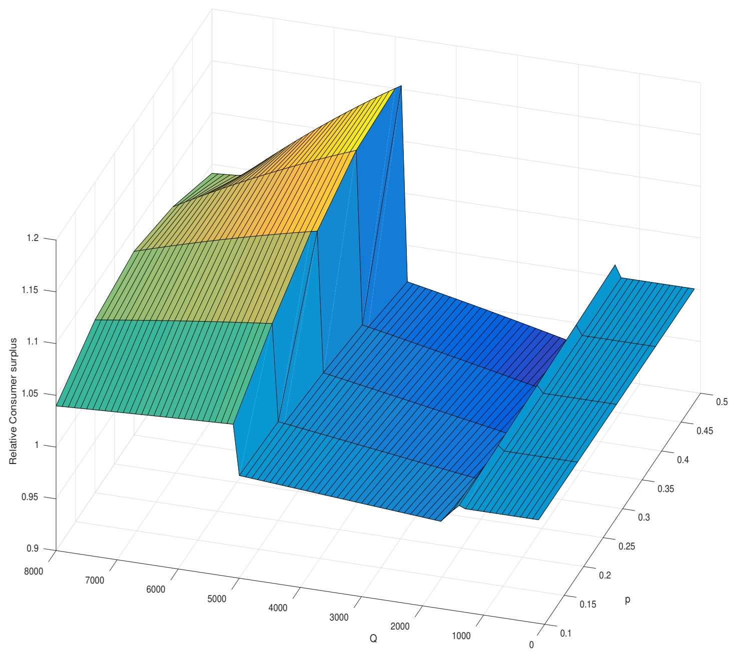

Figure 6: Consumers' surplus of price floor (relative to *laissez-faire*), in the case where the cost of the policy is paid by the consumers (e.g., public taxes).

These observations lead to the following Result.

Result 1 *A price floor policy is always socially desirable from a global point of view. However, in the case where the consumer has to finance the policy as a taxpayer, the policy is detrimental for the consumer-taxpayer in the event of a storm of an intermediate magnitude, i.e., 0.5 to 2 harvest periods.*

4.2 Comparing two policy tools: storage vs. price floor

In this section, we propose to compare price floor and storage.

Figure 7 depicts the social welfare of each policy, price floor and storage, relative to *laissez-faire*. These simulations are still run with our benchmark scenario described in Table 1. We can see that for storms of a low magnitude (with $Q < 4980$), from a global perspective, the policy of storage is socially preferable to a policy of price floor. But for the highest magnitudes of storm, the reverse holds: price floor is socially preferred to

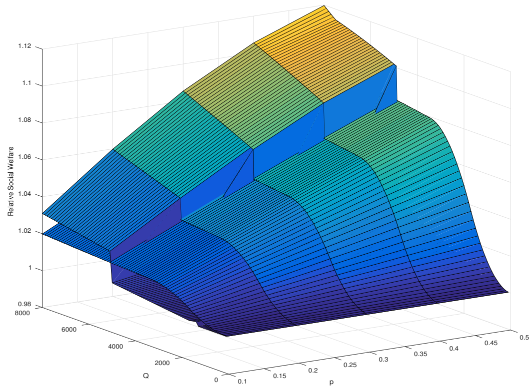

Figure 7: Social welfare of price floor policy and storage (both relative to *laissez-faire*).

storage. This so despite a high cost of implementing price floors,[13] because price floors allow consumers to enjoy a high supply of wood - and especially harvested wood - on the market, at a lower price than storage.[14]

We thus obtained the following Result.

Result 2 *A storage policy is socially preferred to a price floor policy in case of storm of low magnitude ($Q < 4980$, i.e. a storm equivalent to two harvests periods), otherwise a price floor policy is preferred.*

We have now to proceed to a sensitivity analysis, to analyze in what extent our results are sensitive in a change in the context.

4.3 Sensitivity analysis

In Appendix B, we develop a sensitivity analysis to check how our results are sensitive to a change in the context, and especially to a change in: (i) the elasticity of substitution between the two kinds of wood (δ) (Appendix B.1), (ii) the price-elasticity of demands for each kind of wood (β and β_R) (Appendix B.2) and, (iii) the levels of the price floors ($\bar{P}_{min}$ and $\underline{P}_{min}$) (Appendix B.3).

[13]In case of a storm of a magnitude $Q = 6000$, the cost of implementing price floors is equal to 1 116 212, while the cost of storage is 7599 (as calculated in Jacob et al. (2024)).

[14]In case of a storm of a magnitude $Q = 6000$, in case of price floors the consumers have an offered quantity of harvested wood QR_0 equal to 2654, for a price $P_{\bar{Q}}(QR_0, Q)$ of 338. In case of storage, we have: $QR_0 = 2377$ and $P_{\bar{Q}}(QR_0, Q) = 1000.5$. As regards windfall, in each policy the price is fallen to zero (saturated market).

4.3.1 Sensitivity to a change in δ

First, we check if the ranking between storage and price floors is sensitive to a change in the elasticity of substitution between the two kinds of wood (δ). Recalling that the benchmark value is $\delta = 0.1$, we have tested both for a downward change (δ =0.05) and an upward change (δ =0.3) ; see Figures 8 and 9 in Appendix B.1. We observe that a reduction in the value of δ favors storage relatively to price floors, and the opposite holds in case of an increase in δ. Recall that a low value of δ means a low substitution between the two kinds of wood: the two markets are highly segmented. In that case, a movement on one market has few impact on the price on the other market: for instance, it is possible for the forester to increase the quantity of harvested wood QR_0 with few impact in terms of decreasing the price of windfall $P_{\underline{Q}}(Q, QR_0)$. Considering the case of price floors, a decrease in δ leads the floors to be triggered for higher magnitudes of storm: the policy is less often implemented.[15] As regards the policy of storage, in case of segmented markets, the beneficial effect of storage is the highest for the forester: it is possible to keep a (relatively) high level of price for windfall by spreading the excess in supply (due to the storm) over several periods. This allow the forester to increase the quantities of harvested wood, offering a high supply in all kinds of wood, over all periods, to the consumer - which is welfare improving (see Jacob et al. (2024) section 3.3.). All in all, in case of a low value of δ, benefits from price floor are lower while the benefits from storage are high, and the reverse holds in case of a higher substitution between the two kinds of wood: the beneficial effect of storage decrease (pushing the forester to restrict the quantities of harvested wood, which is welfare losing), while the benefit from price floors, in terms of providing support to the forester to maintain the supply of wood, is higher.

We can summarize these findings as follows :

Result 3 *A high substitution between the two kinds of wood (harvested and windfall) is beneficial to a policy of price floor, while a low substitution between the two qualities of wood provides support to a policy of storage.*

[15] Starting from our benchmark scenario displayed in Table 1, a decrease in δ from 0.1 to 0.05 leads to increase in the values of Q needed to trigger price floors. The floor $\underline{P}_{min}$ is triggered for $Q = 1460$ (instead of $Q = 1320$), and the floor $\bar{P}_{min}$ is triggered for $Q = 8780$ (instead of $Q = 4980$).

4.3.2 Sensitivity to a change in β and β_R

Second, we analyze if the ranking between price floors and storage is sensitive to a change in price-elasticities of demands for wood, β and β_R. Recalling that the benchmark values are $\beta = 0.8$ and $\beta_R = 0.4$, we test for two downward changes: $\beta = 0.6$; $\beta_R = 0.2$ and $\beta = 0.3$ and $\beta_R = 0.1$, and two upward changes: $\beta = 1$; $\beta_R = 0.5$ and $\beta = 1.2$; $\beta_R = 0.8$. Figures 10 and 11 in Appendix B.2 refer to the downward changes, and Figures 12 and 13 refer in Appendix B.2 to the upward changes.

We observe that when the values of β and β_R decrease (i.e., when the demands for wood are less elastic), storage becomes less relevant as it is documented in Jacob et al. (2024). Indeed, given that storage aims at avoiding a fall in price by smoothing the excess in supply (of windfall, following a storm) over several periods, in a case where the price of wood decreases at a very slow rate when supply increases, the efficiency of storage is less salient. It is even dominated by price floor when $\beta = 0.3$ and $\beta_R = 0.1$. Conversly, as the demand becomes more elastic (higher values of β and β_R), the relative performance of storage increases ; and even more when the values of β and β_R get closer: for $\beta = 1.2$ and $\beta_R = 0.8$, storage dominates price floor.

Result 4 *Low price-elasticities of demands for wood favors a policy of price floor, while higher (and close) price-elasticities of demands for wood favors a policy of storage.*

4.3.3 Sensitivity to a change in the levels of price floors, $\bar{P}_{min}$ and $\underline{P}_{min}$

Finally, we test in what extent the ranking between both policies is sensitive to a change in the levels of the price floors $\bar{P}_{min}$ and $\underline{P}_{min}$. Recall that the level of price floors in the benchmark scenario are: $\bar{P}_{min} = 500$, $\underline{P}_{min} = 300$. We test for a downward change in the level of price floors: $\bar{P}_{min} = 50$; $\underline{P}_{min} = 30$ and for two upward changes: $\bar{P}_{min} = 800$; $\underline{P}_{min} = 500$ and $\bar{P}_{min} = 1000$; $\underline{P}_{min} = 600$.

Lower levels of price floors make that policy closer to a *laissez-faire* one: for $\bar{P}_{min} = 50$ and $\underline{P}_{min} = 30$, the policy of storage strictly dominates. While our benchmark scenario highlights a trade-off between storage (dominant for low magnitudes of storm) and price floor (dominant for high magnitudes of storm), our sensitivity analysis reveals that the relative desirability of price floor is resilient to an upward change in the levels of floors. Despite a sharp increase in the cost of implementing the policy - because floors trigger for lower magnitude of storms,[16] as highlighted by Figure 15 in Appendix B.2 - the relative desirability of the policy increases because of a forester offering a higher quantity of harvested wood, thanks to the perspective of a preserved profit in case of decreases in prices. Note that for price floor level of $\bar{P}_{min} = 1000$ and $\underline{P}_{min} = 600$, the price floor policy is dominated by the policy of storage only when the cost of using public funds λ is higher than 1.5.

Result 5 *Because it provides the forester with a strong incentive to increase the quantity of harvested wood offers, increasing the levels of price floors don't always worsen the relative desirability of the policy. The relative desirability of price floor is called into question when the cost of using public funds is high (i.e.,* $\lambda > 1.5$*).*

5 Discussion and conclusion

In this article, we propose a tractable theoretical model which allows us to capture the viewpoints of the various actors following a supply shock on a commodities market generating a fall in prices. We model a public management tool acting on price (price floor) and another acting on quantity (storage) in order to compare them from the point of view of the different actors. We apply this to the case study of a storm leading to an increase in the supply of wood and a sharp fall in the price of wood in the market. The actors considered are the (upstream) forester, the (downstream) consumers and the public authority. This model offers a certain level of genericity, since it can be applied to many commodities likely to be affected by a supply shock. We consider windfall as a commodity which may also be relevant in other situations like agricultural product after a frost or water production after drought period. In addition, the tools modeled may be extended. Indeed, we model a fall in price but if the supply shock leads to an increase in the price of the product, then the price floor becomes a ceiling price, and the model can easily be adapted. At the opposite, storage seems to be relevant only in case of fall in price.

Several interesting results emerge from this model.

First, when comparing a price floor policy to a policy of *laissez-faire* (no policy), we

[16] When $\bar{P}_{min} = 800$; $\underline{P}_{min} = 500$, both floors are triggered as soon as $Q > 1340$. In the benchmark scenario, the two floors are triggered only when $Q > 4980$.

observe that price floor is always desirable, and the degree of social desirability increases with the magnitude of storm. When looking more precisely to the consumers' point of view, the desirability of price floor can be questioned especially in the case of storm of intermediate magnitude (between 0.5 and 2 periods of normal harvest). Indeed, in that case, if the consumers are also considered as to be the taxpayers (who have to finance the public policy), then price floor make them worse-off than *laissez-faire*.

Second, when comparing price floor with storage, we show that storage is preferable for storms of low magnitude (2 periods of normal harvest), and price floors for highest magnitudes. We can deepen our analysis a little bit on that point. Indeed, in Jacob et al. (2024), the authors show that, for a storage policy, the consumer lose if $Q < 3400$ and, in the paper at hands, we show that, for a price floor policy, the consumer-taxpayer lose for $1450 < Q < 4980$. This means that between $Q = 1450$ and $Q = 3400$ none of the two policies considered is desirable for the consumers(-taxpayers). Such a magnitude corresponds to 0.6 and 1.4 periods of harvest.
Sensitivity analysis challenged this ranking. On the one hand, a high degree of substitution between the two qualities of wood provides support to price floor whereas a low degree favors storage. On the other hand, low price-elasticities of demands for wood favor a policy of price floor, while higher (and close) price-elasticities of demands for wood favors a policy of storage.

Finally, our results reveal that the policy of price floors is relatively resilient in an increase in the levels of price floors, except in the case where the cost of using public funds is very high ($\lambda > 1.5$).

To conclude, we can see that implementing one policy or the other one depends both on technical features, like the magnitude of the storm, the substitution between kinds of woods, the price-elasticities of demands, but it also depends on political trade-offs, between the consumers and the foresters well-being. While expertise is required, politics remains crucial.

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A Appendix related to the theoretical part of the article

A.1 Price floor: case of market price falling to zero

The rationale of price floor is similar to those that was introduced in the body of the article: when a market price falls below a price floor, then the public agent pays a subsidy to the forester which amounts, for each sold quantity, to the difference between the floor and the market price.

However, when the market price falls to zero (what was not introduced in the body of the article), the consumers only demand the quantity for which the price falls to zero. As developed in Appendix A for the case of *laissez-faire*, given that we assume $\alpha_R > \alpha$ and $\beta_R < \beta$, the demand for harvested wood is higher than the demand for windfall. As a result, the price for windfall reaches zero "more quickly" that the price of harvested wood. It results that price(s) falling to zero can arrive in Case 2 and in Case 4 (described in section 2.3.1).

In Case 2 (when both price floors $\bar{P}_{min}$ and $\underline{P}_{min}$ are triggered), two situations have to be distinguished: when only the price for windfall falls to zero, and when both prices (windfall and harvested wood) fall to zero.

When only the price of windfall falls to zero, the quantity which is demanded by the consumers is:

$$Q|_{P_{\underline{Q}}=0} = \frac{\alpha - \delta QR_0}{\beta}$$

which satisfies: $P_{\underline{Q}}(Q, QR_0) = 0$, given QR_0.
It results that only $Q|_{P_{\underline{Q}}=0}$ is bought by consumers (and $Q - Q|_{P_{\underline{Q}}=0}$ is waste). The forester's profit in period 1 in case of storm is:

$$\Pi_1^H = \underline{P}_{min} Q|_{P_{\underline{Q}}=0} + \bar{P}_{min} QR_0^* - \underline{k}Q - \bar{k}QR_1^H + P_{\bar{Q}}(QR_1^H)QR_1^H$$

The consumers' surplus in case of storm is:

$$CS^H = \frac{1}{2}\beta(Q|_{P_{\underline{Q}}=0})^2 + \frac{1}{2}\beta_R(QR_0^*)^2 + \frac{1}{2}\beta_R(QR_1^H)^2$$

And the policy cost is equal to:

$$\left[(\underline{P}_{min} - 0)Q|_{P_{\underline{Q}}=0} + (\bar{P}_{min} - P_{\bar{Q}}(QR_0^*, Q|_{P_{\underline{Q}}=0}))QR_0^*\right]\lambda \tag{4}$$

with $P_{\bar{Q}}(QR_0^*, Q|_{P_{\underline{Q}}=0}) = \alpha_R - \beta_R QR_0^* - \delta Q|_{P_{\underline{Q}}=0}$ the market price of the harvested wood, when the market price for windfall has fallen to zero.
Note that what changes relatively to the case where the price remains positive is the quantity of windfall consumed by the consumers, which has an impact on their surplus, on the price of the harvested wood $P_{\bar{Q}}(QR_0^*, Q|_{P_{\underline{Q}}=0})$, and on the cost of the policy.

When both prices of windfall and harvested wood fall to zero, the quantity of windfall that is bought by the consumers is: $Q|_{P_{\underline{Q}}=0}$. As regards harvested wood, the quantity which is demanded satisfies: $P_{\bar{Q}}(QR_0, Q) = 0$, given Q. This quantity is:

$$QR_0|_{P_{\bar{Q}}=0} = \frac{\alpha_R - \delta Q}{\beta_R}$$

It results that only $Q|_{P_{\underline{Q}}=0}$ (for windfall) and $QR_0|_{P_{\bar{Q}}=0}$ (for harvested wood) are bought by consumers ($Q - Q|_{P_{\underline{Q}}=0}$ and $QR_0^* - QR_0|_{P_{\bar{Q}}=0}$ are waste). The forester's profit in period 1 in case of storm is:

$$\Pi_1^H = \underline{P}_{min} Q|_{P_{\underline{Q}}=0} + \bar{P}_{min} QR_0|_{P_{\bar{Q}}=0} - \underline{k}Q - \bar{k}QR_1^H + P_{\bar{Q}}(QR_1^H)QR_1^H$$

The consumers' surplus in case of storm is:

$$CS^H = \frac{1}{2}\beta(Q|_{P_{\underline{Q}}=0})^2 + \frac{1}{2}\beta_R(QR_0|_{P_{\bar{Q}}=0})^2 + \frac{1}{2}\beta_R(QR_1^H)^2$$

And the cost of the policy is equal to: $\left[(\underline{P}_{min} - 0)Q|_{P_{\underline{Q}}=0} + (\bar{P}_{min} - 0)QR_0|_{P_{\bar{Q}}=0}\right]\lambda$

In Case 4 (when only the price floor $\underline{P}_{min}$ is triggered), the situation is the same as in the Case 2 when only the price for windfall falls to zero.

♦

A.2 Values of QR_0^* in the case of a price floors policy

In case of a price floors policy, the optimal value of QR_0 aims at maximizing the expected profit given by Eq. (2), which is:

$$E[\Pi_0(QR_0)] = -\overline{k}QR_0 + p\Pi_1^T\left(QR_1^{H*}\right) + (1-p)\Pi_1^{NH}\left(QR_1^{NH*}\right)$$

As explained in the body of the paper, here the value of $\Pi_1^H(QR_1^{H*})$ is different depending on which price floor is triggered. Four different cases have to be distinguished, leading to four different values of QR_0^*.

Before developing the four cases, we can first determine the value of $\frac{\Pi_1^{NH}(QR_1^{NH*})}{\partial QR_0}$, which is necessary to maximize Eq. (2). We have:

$$\frac{\Pi_1^{NH}(QR_1^{NH*})}{\partial QR_0} = \alpha_R - 2\beta_R QR_0 \tag{5}$$

Then, depending on which of the four cases about the triggering of price floors in $\Pi_1^H(QR_1^{H*})$ applies, we have four possible optimal values of QR_0.

In Case 1 (no price floor is triggered), the value of $\Pi_1^H(QR_1^{H*})$ is:

$$P_{\overline{Q}}(QR_0,Q)QR_0 - \overline{k}QR_1^H + P_{\underline{Q}}(Q,QR_0)Q - \underline{k}Q + P_{\overline{Q}}(QR_1^H)QR_1^H \tag{6}$$

Solving $\frac{\partial E[\Pi_0(QR_0)]}{\partial QR_0} = 0$ knowing Eq. (6) and Eq. (5) leads to an optimal value QR_{0-1}^* equals to:

$$QR_{0-1}^* = \frac{\alpha_R - 2p\delta Q - \overline{k}}{2\beta_R} \tag{7}$$

In Case 2 (both price floors are triggered), the value of $\Pi_1^H(QR_1^{H*})$ is:

$$\overline{P}_{min}QR_0 - \overline{k}QR_1^H + \underline{P}_{min}Q - \underline{k}Q + P_{\overline{Q}}(QR_1^H)QR_1^H \tag{8}$$

Solving $\frac{\partial E[\Pi_0(QR_0)]}{\partial QR_0} = 0$ knowing Eq. (8) and Eq. (5) leads to an optimal value QR_{0-2}^* equals to:

$$QR_{0-2}^* = \frac{(1-p)\alpha_R + p\overline{P}_{min} - \overline{k}}{(1-p)2\beta_R} \tag{9}$$

In case 3 (the price floor on high quality is triggered), the value of $\Pi_1^H(QR_1^{H*})$ is:

$$\overline{P}_{min}QR_0 - \overline{k}QR_1^H + P_{\underline{Q}}(Q, QR_0)Q - \underline{k}Q + P_{\overline{Q}}(QR_1^H)QR_1^H \tag{10}$$

Solving $\frac{\partial E[\Pi_0(QR_0)]}{\partial QR_0} = 0$ knowing Eq. (10) and Eq. (5) leads to an optimal value QR_{0-3}^* equals to:

$$QR_{0-3}^* = \frac{(1-p)\alpha_R + p\left[\overline{P}_{min} - \delta Q\right] - \overline{k}}{(1-p)2\beta_R} \tag{11}$$

In Case 4 (the price floor on low quality is triggered), the value of $\Pi_1^H(QR_1^{H*})$ is:

$$P_{\overline{Q}}(QR_0, Q)QR_0 - \overline{k}QR_1^H + \underline{P}_{min}Q - \underline{k}Q + P_{\overline{Q}}(QR_1^H)QR_1^H \tag{12}$$

Solving $\frac{\partial E[\Pi_0(QR_0)]}{\partial QR_0} = 0$ knowing Eq. (12) and Eq. (5) leads to an optimal value QR_{0-4}^* equals to:

$$QR_{0-4}^* = \frac{\alpha_R + p\delta Q - \overline{k}}{2\beta_R} \tag{13}$$

♦

B Sensitivity analysis

In this section, we present the results of sensitivity analyses realized on several parameters : δ, β and β_R, $\underline{P}_{min}$ and $\overline{P}_{min}$. The following table presents the values tested for these different parameters in the sensitivity analysis.

Table 2: Values of the parameters for the sensitivity analysis.

Parameter	Values in the benchmark scenario	Sensitivity
$\overline{P}_{min}$	500	[50 / 800]
$\underline{P}_{min}$	300	[30 / 500]
λ	1.2	[1.1/1.5]
δ	.1	[.05 / .3]
β_R	.4	[.2 / .7]
β	.8	[.3 / .6]

The benchmark scenario is the scenario which is adopted in our first simulations made in sections 4.1 and 4.2. Thus it recall the values of parameters given in Table 1.

B.1 Sensitivity analysis on δ

In the benchmark scenario, $\delta = 0.1$. We look at the impact of changing δ with $\delta = 0.05$ and $\delta = 0.3$ on the social welfare for each case.

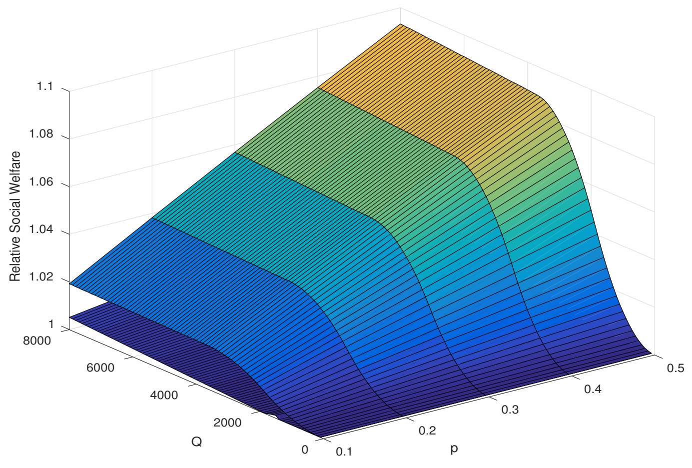

Figure 8: Social welfare relative to no public policy, with δ=0.05.

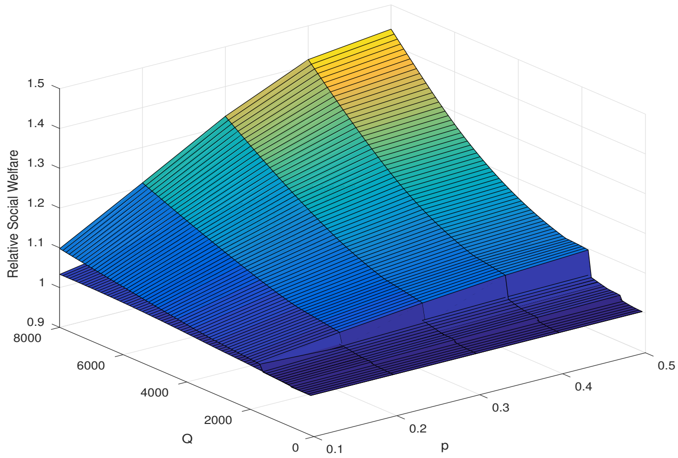

Figure 9: Social welfare relative to no public policy, with δ=0.30.

B.2 Sensitivity analysis on β and β_R

Recalling that the benchmark values are $\beta = 0.8$ and $\beta_R = 0.4$, we test for two downward changes: $\beta = 0.6$; $\beta_R = 0.2$ and $\beta = 0.3$; $\beta_R = 0.1$, and two upward changes: $\beta = 1$; $\beta_R = 0.5$ and $\beta = 1.2$; $\beta_R = 0.8$.

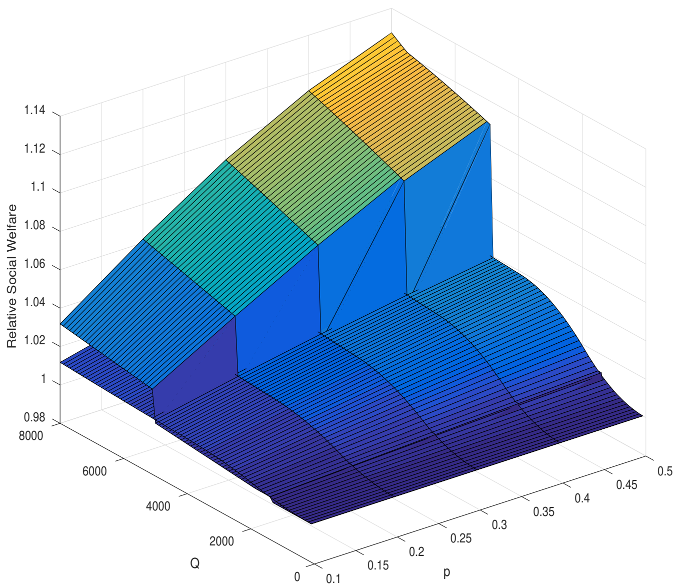

Figure 10: Social welfare of price floor vs. storage, relative to *laissez-faire*, with β=0.6 and β_R=0.2.

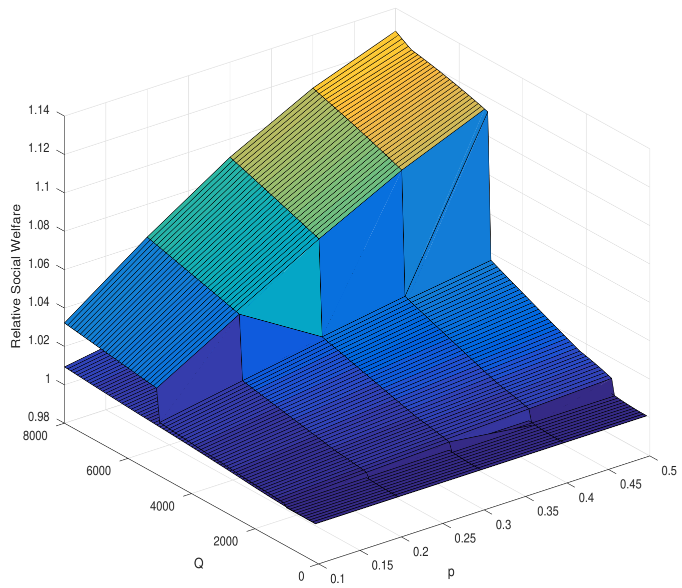

Figure 11: Social welfare of price floor vs. storage, relative to *laissez-faire*, with β=0.3 and β_R=0.1.

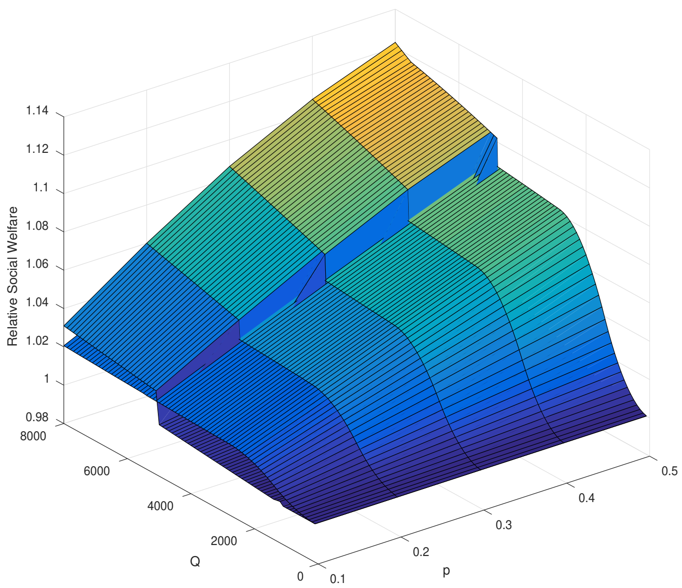

Figure 12: Social welfare of price floor vs. storage, relative to *laissez-faire*, for $\beta = 1$ and $\beta_R = 0.5$.

B.3 Floor price levels

Recall that the level of price floors in the benchmark scenario are: $\bar{P}_{min} = 500$, $\underline{P}_{min} = 300$. We test for a downward change in the level of price floors: $\bar{P}_{min} = 50$;

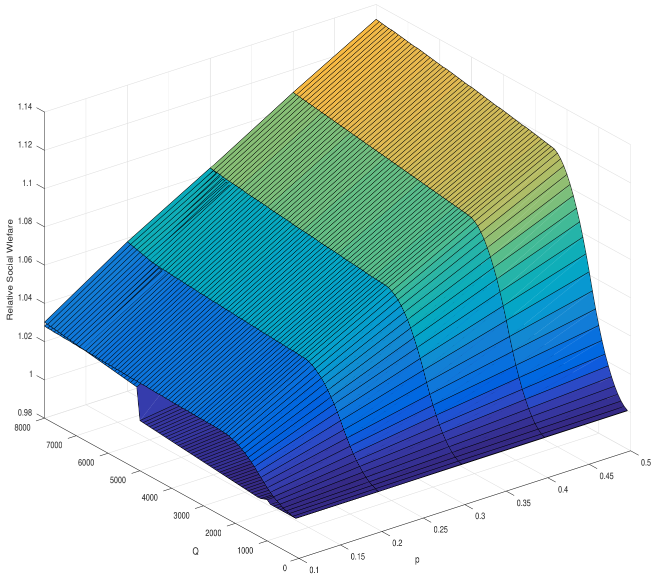

Figure 13: Social welfare of price floor vs. storage, relative to *laissez-faire*, for $\beta = 1.2$ and $\beta_R = 0.8$.

$\underline{P}_{min} = 30$, and for two upward changes: $\bar{P}_{min} = 800$; $\underline{P}_{min} = 500$ and $\bar{P}_{min} = 1000$; $\underline{P}_{min} = 600$.

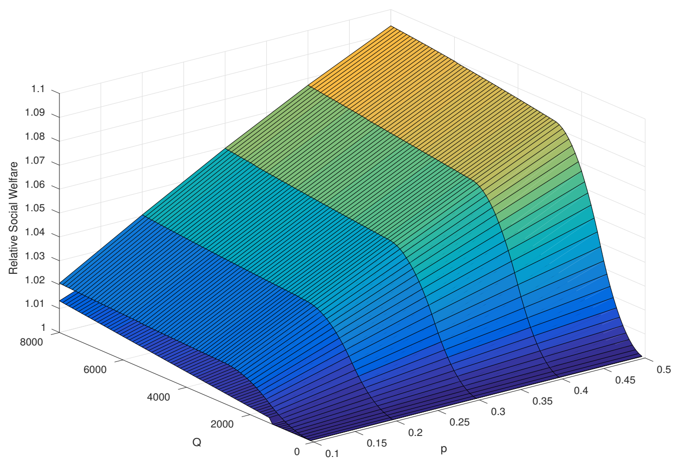

Figure 14: Social welfare relative to no public policy, with $\bar{P}_{min}$=50 and $\underline{P}_{min}$=30.

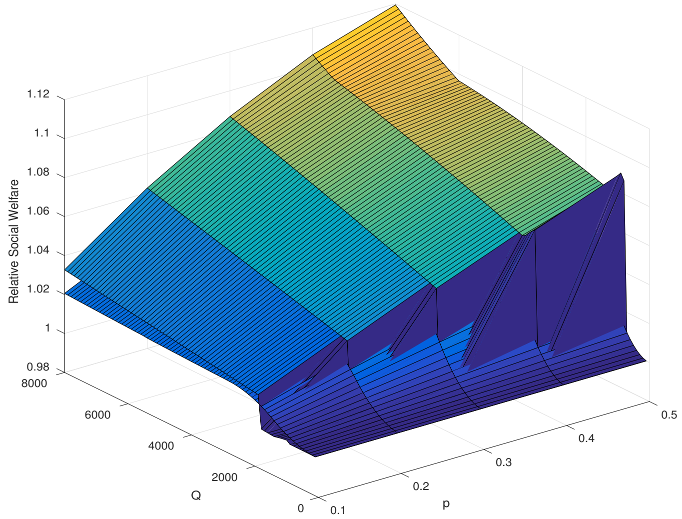

Figure 15: Social welfare relative to no public policy, with $\bar{P}_{min}$=800 and $\underline{P}_{min}$=500.

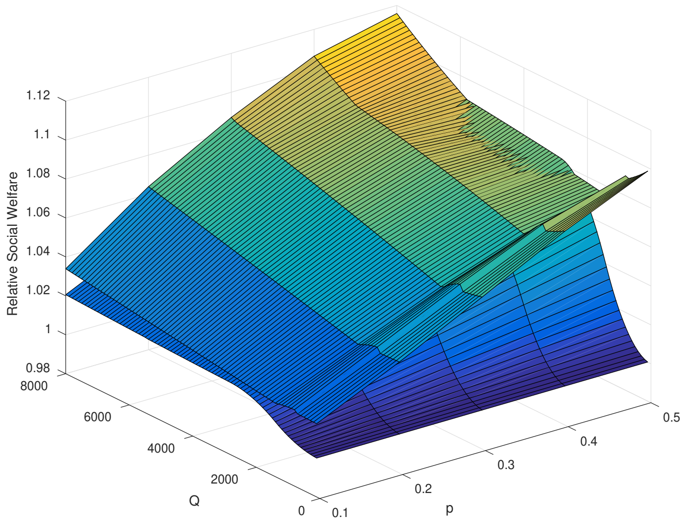

Figure 16: Social welfare relative to no public policy, with $\bar{P}_{min}$=1000 and $\underline{P}_{min}$=600.

C Additional figures

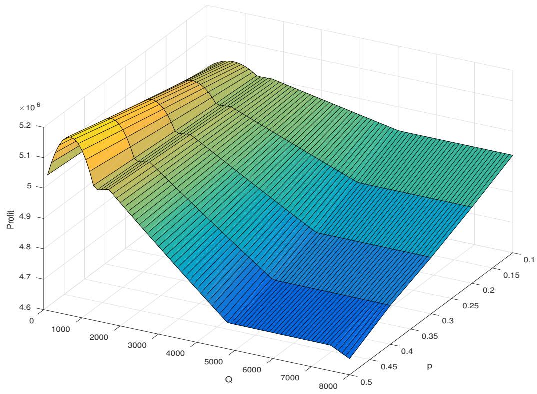

Figure 17: Forester's profit in the case of price floor policy (absolute value).

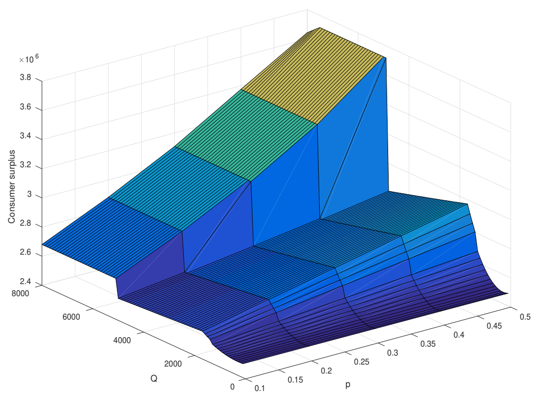

Figure 18: Consumers' surplus in the case of price floor policy (absolute value).