Interventions in the Pharmaceutical Sector:
Price Ceiling versus Maximum Profit Percentage

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Bachelor Thesis

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Abstract

Monopolistic behavior leads to market inefficiencies, but in a market so heavily dependent on research and development, this does not appear to be a problem that is easily tackled. Several politicians and economists have made arguments in favor of particular government interventions.
The aim of this thesis is to answer the question whether either a price cap or a profit margin cap would lead to the highest total welfare (or possibly a combination of both). Analyzing a simple monopolistic market model facing a downward sloping linear demand curve will be the attempt to answer this question.
We find that the price ceiling performs worst in terms of total welfare, not evidently performing much better than the market without intervention. The profit margin cap performs better, however, the combination of both interventions can accomplish results in terms of total welfare that exceed those of the interventions individually. The model indicates the importance of taking in mind effects on R&D decisions when implementing a certain intervention.

Contents

1 Introduction

1.1 Motivation and Problem Statement

Orphan drug pricing has reignited the decades-old debate on the role of the government in the pharmaceutical sector. Should there be intervention, or should we leave the free market at play, to stimulate investments in research and development? And if there should be intervention, of what kind should this intervention be? In this thesis I will provide a simple monopoly model, in which I will display two interventions. The main question is whether in this representation of the pharmaceutical market for orphan drugs, intervention leads to welfare gains, and if so, whether differences in outcomes among the options for intervention exist.

Orphan drugs are a type of drugs, specific to rare diseases that less than 5 in 10000 people suffer from [12]. Often only one type of drug is available for such rare diseases, as entry as a second firm in the market quickly becomes unattractive in a market of such small size. Due to this, monopolistic market power arises. This market power leads to the pharmaceutical companies being able to charge very high prices for these drugs, as demand in the orphan drug sector can be seen to be near perfectly inelastic [9].

In the Netherlands, debate was instigated in the mainstream media in 2016, when Radar, a Dutch television show, aired an episode focused on the problems arising due to these pricing strategies [10]. It was argued that we should start to get worried about insurers not providing these drugs anymore. The price paid for orphan drugs in the Netherlands has risen from 61.2 million euros in 2006 to 260 million euros in 2012. In 2017, the problem was again referred to on national television, this time on NOS Journaal. There it was mentioned that pharmacists were indignant at pharmaceutical companies buying the rights to produce a drug only to raise the price of the medicine without adding any value to it [7][1].

Monopoly power can be especially harmful in the case of pharmaceuticals as this product can be considered to face a relatively steep and thus inelastic inverse demand curve. This steepness of the demand curve is explained by the low responsiveness of the consumer to price increases.

1.2 Method

In this thesis, a theoretical model approach will be used to estimate what effects market interventions may have in a market that is as heavily dependent on R&D as the market for pharmaceuticals arguably is. We will use a textbook example of the simple monopolistic market, as can be found in Besanko et al.(2014)[4], and amend this model by adding a positive effect of R&D to the demand function.

Four interventions will be compared in terms of their performance regarding total welfare. Results will be analyzed using software such as Python and Wolfram|Alpha[2]. The interventions that will be compared are a total welfare maximizing government-owned pharmaceutical company, a price ceiling, a maximum allowable profit margin and a combination of the price ceiling and the maximum profit margin.

2 Proposed Interventions

Government intervention is a much-debated topic in economics. On the one side, market economists argue that a market will function at its maximum potential if it is left alone. Nevertheless, in the case of pharmaceutical drug pricing, and more specifically in the case of orphan drugs, market failures arise due to monopolistic market power of the companies that are active in the market. To tackle these market irregularities however is not as easy as one might conclude at first sight. While in a more simple market model it might seem optimal to set a maximum price forcing the companies to price their product at marginal costs and thereby maximize total welfare, the market for medicine is vastly dependent on the investment choices regarding research and development.

In the pharmaceutical market, innovation may be argued to lead to an upward shift of the demand curve. This upward shift can be interpreted by either creating more welfare per consumer (e.g. by getting rid of harmful side effects). Or secondly, by providing innovative drugs that increase the number of sales by having a broader reach.

Besides, authorities may still want to regard it as a goal to increase investments in the pharmaceutical sector, as innovative medicines can have many positive externalities. Establishing the attractiveness of such investments might require the authorities to still leave significant profit levels to the suppliers of medicine.

According to Chressanthis(2008)[6], the problems faced by an economist in the pharmaceutical industry include policy pressures implied by price regulations particularly favoring the generic brand drug manufacturers and thus negatively affecting the margins that are demanded to operate effective drug innovation. After all, bringing a new drug to the market remains a risky investment, costing an estimated average of 932 million dollars and taking up 13 years. The argument that a conservative defender of the industry could make – the pharmaceutical market should be free, because it resembles the worth of the life saving piece of technology – is hardly still anywhere to be found. There is very much an agreement in the literature that moral values are at play in this situation, we cannot afford to exclude people from life saving drugs by imposing prices that are unreasonably high. However, the discussion that remains is that of the type of regulation.

Some, such as the Dutch ex-politician Wouter Bos, argue that a maximum profit level should be implemented. As the levels that companies are currently aiming for (about 20%) exceed any financial necessity. He argues that we are allowing these companies to play a dominant role towards patients who have no choice. Bos points towards the success of the implementation of a profit cap in other industries such as telecommunication[8].

Others have argued for other types of price regulations. Joe Stiglitz, an American economist argues for a medical prize fund that rewards those who discover cures and vaccines to replace the system of patents that is currently in place. The prize fund would lead to incentives to innovate beyond the scope at which patents do, as with the current system of patents, companies are relatively more incentivized to invest in lifestyle drugs that are of much less value to society rather than life-saving drugs (anti-hair loss product vs. malaria drug) [11].

Another proposal, proposed by Martin Skhreli (the person that has been criticized by much of mainstream media of taking advantage of the current system by increasing a HIV drugs' price from $13.50 to $750 overnight), is that "the government should run a drug company". Skhreli argues that the idea of state-owned enterprises producing drugs has had much success in other countries (China, Russia). Skhreli claims that governments supplying drugs at cost price would counter rent seekers buying up rights to produce drugs with little competition, as is the case many times with orphan drugs, in order to increase the price up to an inefficiently high level, from a total welfare perspective.[5]

In the model that is used in this thesis, the main question is whether there will be a notable difference in outcomes if the proposal by Wouter Bos[8] is used, compared to the textbook example of a government intervention, a price ceiling and the theoretical model of the model proposed by Martin Skhreli[5], namely that of the state owned drug producing enterprise.

3 The Model

3.1 Assumptions

In the model, there are some assumptions that have to be made.

- There is one firm supplying the market hence there are no close substitutes, thus a monopoly arises. This is a necessary condition as the main interest lies in the monopolistic markets that are present in production and consumption of orphan drugs. These monopolies arise due to high entry barriers. An example of an entry barrier in the market for orphan drugs is patents, patents exclude entrants from producing a product that is identical to the product of the incumbent. This forces entrants to face the costs of develop a new drug, costs which are more likely not to weigh up to the potential profits in a market which has such a low coverage as the market for orphan drugs.

- The demand curve is linear, negatively sloped. This assumption helps identifying the effects of measures without adding complexity to the model. Although the demand curve is nearly perfectly inelastic, we use a negatively sloped curve to derive our welfare outcomes, we can choose various values for our parameters to find out how our outcomes might behave for different steepnesses.

- The monopolist sets quantity (Q) and research and development investments (y) to maximize profits.

- The model is static. The monopolist does not face a multi-period decision problem, instead it chooses only one research and development investment level and one quantity level.

- The demand curve is positively affected by R&D investments. The rationale behind this is that an investment in R&D might improve or lead to the invention of drugs. This is then reflected in the demand curve by an upward shift as a reaction to investments in R&D.

- The competition authority aims to maximize total welfare.

3.2 Variables and Functions

First, let us define some variables. Variables and their definitions can be found in Table 3.1.

Variable	Definition
a, b, c, d, e	Constants, a particular fixed value will be assigned to these variables
y	The level of R&D investments, chosen by the monopolist.
Q	Quantity supplied by the firm
P	Price that is implied by the other variables
CW	Consumer welfare, total value of the product to the consumer
π	Monopolist profits
$TW = CW + \pi$	Total welfare to society
$\bar{P}$	Maximum price set by the consumer authority
$\bar{z}$	Maximum profit margin set by the consumer authority
TC	Total cost to the firm

Tab. 3.1: Variables and their Definitions

For some of the variables defined in 3.1 we should define some ranges:

$a > 0$, If this condition would not hold, the intercept of the demand curve with the y-axis would not be positive.
$b > 0$, This is a necessary condition for the demand curve to be negatively sloped. We assume that drug prices negatively impact the amount of people buying drugs.
$c \geq 0$, we typically use small variable costs in our model. Nevertheless these costs are positive in value.
$d \geq 0$, fixed cost independent of research investment are mostly ignored in the optimization procedure.
$e > 0$, To study the effect of research investments we need the cost of these investments to be greater than 0.
$y > 0$ and $Q > 0$, Firms cannot invest negative amounts, nor can they supply negative amounts.

Using the variables that were defined in table 3.1, we can construct our model. **(Derivations of functions 3.6, 3.7, 3.8, 3.9, 3.10, 3.11, 3.14, 3.15, 3.16, 3.17, 3.18, 3.19, 3.20, 3.21 3.22 and 3.23 can be found in the Appendix.)** In the model, the monopolist faces an inverse linear demand curve as can be seen in equation 3.1

$$P(y, Q) = (1 + y) \cdot a - b \cdot Q \tag{3.1}$$

Where P is the price following from the choice of inputs y and Q, $((1 + y) \cdot a)$ represents the intersect of the inverse demand curve with the y-axis. $-b$ Is the slope of the demand curve.
Given this inverse demand function P depends positively on the research investments and negatively on the amount of products sold.
The monopolist faces a total cost function displayed in equation 3.2.

$$TC(y, Q) = d + e \cdot y^2 + c \cdot Q \tag{3.2}$$

The cost curve depends on a fixed cost d, a variable cost of c per product sold, and R&D investments with a factor $e \cdot y^2$
The firms' profit is defined as displayed in equation 3.3.

$$\pi(y, Q) = Q \cdot P(y, Q) - TC(y, Q) \tag{3.3}$$

Further, the consumer welfare is defined as the surface of the triangle above the price level and below the inverse demand curve. It is calculated as shown in equation 3.4.

$$CW(y, Q) = \frac{1}{2} \cdot (P(y, Q = 0) - P(y, Q)) \cdot Q \tag{3.4}$$

If we add the consumer welfare to the profits, we obtain the total welfare function shown in equation 3.5.

$$TW(y, Q) = CW(y, Q) + \pi(y, Q) \tag{3.5}$$

3.2.1 No Intervention

From these equations we can derive the monopolists' profit maximizing amount of R&D investment. (equation 3.6)

$$y^*(Q) = \frac{a \cdot Q}{2 \cdot e} \tag{3.6}$$

And quantity. (equation 3.7)

$$Q^*(y) = \frac{(1+y) \cdot a - c}{2 \cdot b} \tag{3.7}$$

Substituting one into the other, we arrive at a profit maximizing combination of input variables y (equation3.8) and Q (equation3.9).

$$y^* = \frac{a^2 - a \cdot c}{4 \cdot e \cdot b - a^2} \tag{3.8}$$

$$Q^* = \frac{(a-c) \cdot 2 \cdot e}{4 \cdot e \cdot b - a^2} \tag{3.9}$$

Following from these equations we can express the price following from optimization of the monopolist in the market without interventions in terms of parameters as well. (equation 3.10)

$$P^* = \frac{a^3 - a^2 \cdot c - 2 \cdot a \cdot b \cdot e + 2 \cdot b \cdot c \cdot e}{4 \cdot b \cdot e - a^2} + a \tag{3.10}$$

In terms of parameters, consumer welfare can then be expressed as shown in equation 3.11.

$$CW^* = \frac{b}{2} \cdot \left(\frac{(a-c) \cdot 2 \cdot e}{4 \cdot e \cdot b - a^2} \right)^2 \tag{3.11}$$

Dead-weight loss of the market without intervention is defined as can be seen in equation 3.12. In this equation, $\tilde{y}$ and $\tilde{Q}$ represent the values chosen in the total welfare maximization case which is further elaborated in the next section of this chapter.

$$DWL = TW(y*, Q^*) - TW(\tilde{y}, \tilde{Q}) \tag{3.12}$$

3.2.2 Total Welfare Maximization

In this section we will study the theoretical case of a state owned enterprise as a drug manufacturer. Supposing that the state owned enterprise aims to maximize total welfare it faces the maximization decision problem as shown in equation 3.13.

$$\underset{y,Q}{\text{maximize}} \quad TW(y,Q) = 0.5(b \cdot Q^2) + Q \cdot ((1+y) \cdot a - b \cdot Q - c) - e \cdot y^2 - d \tag{3.13}$$

From this objective function we can obtain the optimal value for y in terms of Q (equation 3.14), and the optimal value for Q in terms of y (equation 3.15).

$$\tilde{y}(Q) = \frac{a \cdot Q}{2 \cdot e} \tag{3.14}$$

$$\tilde{Q}(y) = \frac{1}{b} \cdot ((1+y) \cdot a - c) \tag{3.15}$$

Substituting one into the other, we arrive at a welfare maximizing combination of input variables y as shown in equation 3.16 and Q as shown in equation 3.17.

$$\tilde{y} = \frac{a \cdot (a-c)}{2 \cdot b \cdot e - a^2} \tag{3.16}$$

$$\tilde{Q} = \frac{2(a-c)}{2 \cdot b - a^2 \cdot e} \tag{3.17}$$

3.2.3 Price Ceiling

The first intervention that is studied will be to introduce a maximum price $\bar{P}$. For this price to affect the monopolists' decision-making process, $\bar{P}$ will need to have a value smaller than the price that would follow from a market without interference. Thus $\bar{P} < P(y^*, Q^*)$. Using a fixed price, we can derive the of $Q(\bar{P}, y)$ (equation 3.18) and $y(\bar{P}, Q)$ (equation 3.19).

$$Q_{\bar{P}}(y, \bar{P}) = \frac{(1+y) \cdot a - \bar{P}}{b} \tag{3.18}$$

$$y_{\bar{P}}(Q, \bar{P}) = \frac{\bar{P} + b \cdot Q}{a} - 1 \tag{3.19}$$

Optimization and substitution gives equations 3.20 and 3.21.

$$Q^*_{\bar{P}}(\bar{P}) = \frac{1}{b} \cdot \left(\left(1 + \frac{a}{2 \cdot e \cdot b} \cdot (\bar{P} - c) \right) \cdot a - \bar{P} \right) \tag{3.20}$$

$$y^*_{\bar{P}}(\bar{P}) = \frac{a}{2 \cdot e \cdot b} \cdot (\bar{P} - c) \tag{3.21}$$

Combining equations 3.20 and 3.21 we can derive the consumer welfare level given a price ceiling in terms of parameters. See equation 3.22.

$$CW^*_{\bar{P}}(\bar{P}) = \frac{1}{b} \cdot \left(\left(1 + \frac{a}{2 \cdot e \cdot b} \cdot (\bar{P} - c) \right) \cdot a - \bar{P} \right)^2 \tag{3.22}$$

Additionally we can calculate the profit level following from the price ceiling in terms of parameters. See equation 3.23.

$$\pi^*_{\bar{P}}(\bar{P}) = \frac{\bar{P} - c}{b} \cdot \left(\left(1 + \frac{a}{2 \cdot e \cdot b} \cdot (\bar{P} - c) \right) \cdot a - \bar{P} \right) - d - \left(\frac{a^2}{4 \cdot e \cdot b^2} \cdot (\bar{P} - c)^2 \right) \tag{3.23}$$

The competition authority would choose a $\bar{P}$ that maximizes total welfare.
This maximization problem can be represented as shown in equation 3.24.

$$\underset{\bar{P}}{\text{maximize}} \quad TW^*_{\bar{P}}(\bar{P}) = CW^*_{\bar{P}}(\bar{P}) + \pi^*_{\bar{P}}(\bar{P}) \tag{3.24}$$

Solving equation 3.24 gives us a welfare maximizing price cap $\tilde{P}$. This welfare maximizing price cap can be expressed in terms of parameters, by solving for $\tilde{P}$ in equation 3.25.

$$\begin{aligned} &\tilde{P}^3(-a^4) + \tilde{P}^2(3a^4c) + \tilde{P}(2a^4b - 3a^4c^2 - 4a^2b^2e) \\ &+a^4c^3 - 2a^4bc + 4a^3b^2e - 4ab^3e^2 + 4b^3e^2c = 0 \end{aligned} \tag{3.25}$$

Dead-weight loss can now be calculated as shown in equation 3.26.

$$DWL = TW(\tilde{P}) - TW(\tilde{y}, \tilde{Q}) \tag{3.26}$$

3.2.4 Profit Margin Cap

The second intervention examined is the profit margin cap, the profit margin cap limits the percentage of profits over revenue that a firm may have. Mathematically, the profit margin cap $(\bar{z})$ is defined as displayed in equation 3.27.

$$\bar{z} = \frac{\pi(y, Q)}{P(y, Q) \cdot Q} \tag{3.27}$$

Thus, the firm faces the maximization problem shown in equation 3.28.

$$\begin{aligned} \underset{y,Q}{\text{maximize}} \quad & \pi(y, Q) = P(y, Q) \cdot Q - TC(y, Q) \\ \text{subject to} \quad & \pi(y, Q) = \bar{z} \cdot P(y, Q) \cdot Q \end{aligned} \tag{3.28}$$

In parameters, the firm maximizes the constraint optimization problem shown in equation 3.29.

$$\begin{aligned} \underset{y,Q}{\text{maximize}} \quad & \pi(y, Q) = Q \cdot ((1 + y) \cdot a - b \cdot Q - c) - d - e \cdot y^2 \\ \text{subject to} \quad & (1 - \bar{z}) \cdot (Q \cdot ((1 + y) \cdot a - b \cdot Q - c)) - d - e \cdot y^2 = 0 \end{aligned} \tag{3.29}$$

Leading to a combination $(y^*_{\bar{z}}, Q\bar{z}^*$ given some parameters for (a,b,c,d,e) and a profit margin cap $(\bar{z})$ set by the competition authority to maximize total welfare.
Solving this maximization problem we derive equilibrium values for inputs y and Q. We obtain Q^* from solving equation 3.30 for Q.

$$\begin{aligned} (z-1)\left(Q\left(\left(1+\left(\frac{a \cdot Q^*(\bar{z}-1)(b \cdot Q^*+1)}{2 \cdot e\,(b \cdot Q^*(z-1)-1)}\right)\right)a - b \cdot Q^* - c\right)\right) \\ +d + e\left(\frac{a \cdot Q^*(\bar{z}-1)(b \cdot Q^*+1)}{2 \cdot e(b \cdot Q^*(z-1)-1)}\right)^2 = 0 \end{aligned} \tag{3.30}$$

Using the value of $Q^*_{\bar{z}}$ we can now find $y^*_{\bar{z}}$ by substituting $Q^*_{\bar{z}}$ for Q in $y^*_{\bar{z}}(Q)$ as shown in equation 3.31.

$$y^*_{\bar{z}}(Q^*_{\bar{z}}) = \frac{a \cdot Q^*_{\bar{z}}(\bar{z}-1)(b \cdot Q^*_{\bar{z}}+1)}{2 \cdot e\,(b \cdot Q^*_{\bar{z}}(z-1)-1)} \tag{3.31}$$

After having found Thus, the competition authority would choose $\bar{z}$ such that $TW(y^*_{\bar{z}}(\bar{z}), Q^*_{\bar{z}}(\bar{z}))$ is maximized. Giving us the total welfare maximizing profit margin cap $\tilde{z}$. Dead-weight loss of the market with a profit margin cap is displayed in equation 3.32.

$$DWL = TW(\tilde{z}) - TW(\tilde{y}, \tilde{Q}) \tag{3.32}$$

4 Results

For our evaluation, we shall assign some values to the constant variables (4.1).

$$(a, b, c, d, e) = (2, 3, 0.1, 0, 1) \tag{4.1}$$

4.1 Welfare Maximizing Firm

Firstly we will calculate outcomes for the market in which the government is the monopolistic drug producer. In this thesis this measure is used as a benchmark for comparing the other interventions to the optimal outcome. The definition of this intervention and its theoretical outcomes automatically imply that it is the "best" intervention in terms of total welfare. Table 4.1 shows results for this intervention given our parameters (4.1).

Statistic	**Values**
	Maximum Welfare
Profit maximizing quantity	1.9
Profit maximizing level of R&D investments	1.9
Profit maximizing price	0.1
Resulting loss	3.61
Consumer welfare	5.415
Total welfare	1.805
Loss margin ($\frac{-\pi}{P(y,Q)*Q}$)	19

Tab. 4.1: Maximum welfare outcomes

4.2 No intervention

Using the values for the parameters (4.1), we can calculate some data in a market without intervention. Table 4.2 shows the results compared to benchmark outcomes for the cases $y = 0$ and $y = 1$.

Statistic	Values		
	No Intervention	**y = 0**	**y=1**
Profit maximizing quantity	0.475	0.317	0.65
Profit maximizing level of R&D investments	0.475	-	-
Profit maximizing price	1.525	1.05	2.05
Resulting profit	0.451	0.301	0.268
Consumer welfare	0.338	0.150	0.634
Total welfare	0.790	0.451	0.901
Profit margin ($\frac{\pi}{P(y,Q)*Q}$)	0.623	0.905	0.201

Tab. 4.2: Equilibrium values without interventions

As can be concluded from table 4.2, in this model, investing $y = 1$ in R&D as opposed to not investing in R&D nearly doubles the value of total welfare.

To provide graphical context to the values in Table 4.2, some figures will be included.

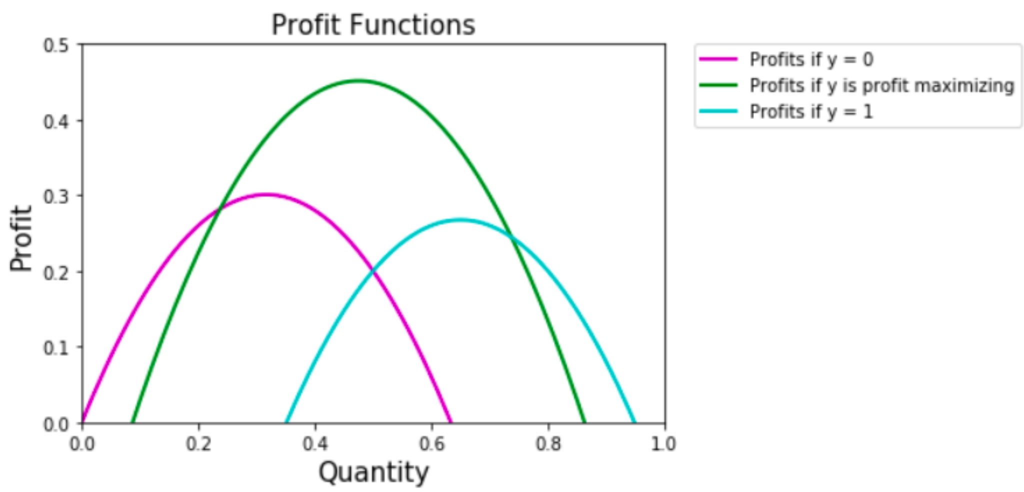

Fig. 4.1: Profit Functions

In figure 4.1 we can see the firm's profit curves for given values of y. With the profit maximizing R&D investment choice, the firm faces the green profit curve, if $y = 0$ it faces the magenta-colored profit curve and it faces the cyan profit curve if $y = 0$.

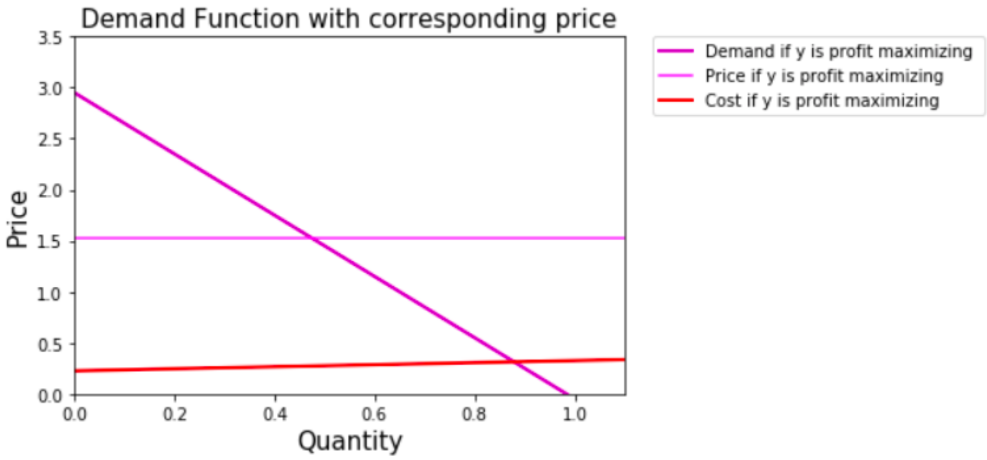

Fig. 4.2: Price, Demand and Cost functions

In figure 4.2 the demand function is plotted along with the price and the total cost curve. In figure 4.2 the consumer welfare is displayed as the triangle above the price and underneath the demand curve. The dead-weight loss, is the area between the cost and demand curves to the right of the intersection of the price and the demand curve.

4.3 Price Ceiling

When introducing a price ceiling, the competition authority faces a problem, which price should be set as the maximum allowable price. The price that is set then sets a limitation on the input combination (y, Q) that the firm may set.
figure 4.3 shows the effect of the set price cap on welfare. Given that the monopolist maximizes its profits.

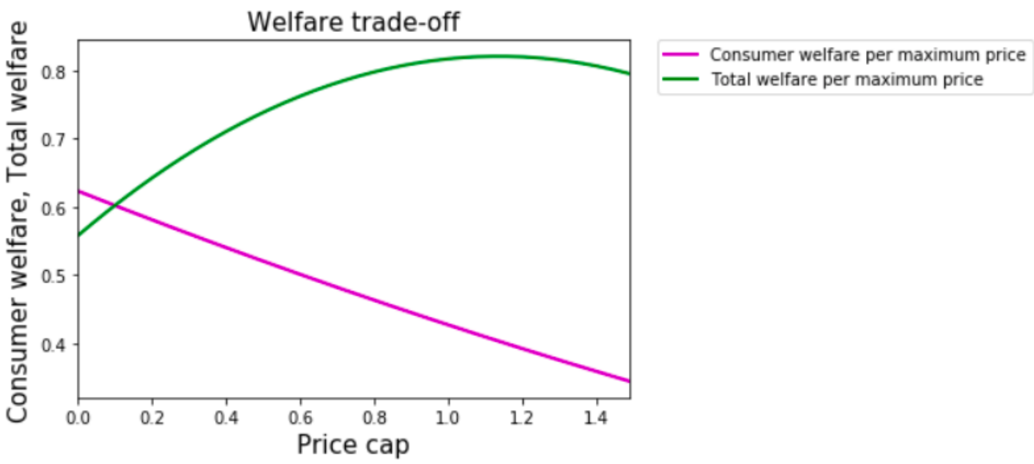

Fig. 4.3: Consumer and Total welfare for different values of $\bar{p}$

Figure 4.3 shows that the consumer welfare decreases as the price cap $\bar{P}$ is increased while the total welfare increases up to a certain point where total welfare is maximized.

From Python's optimization routine we get that the competition authority that maximizes total welfare sets a maximum price $\bar{P} = \frac{25}{22} \approx 1.136$.

The values of our statistics that are of importance, given that the profit-maximizing producer is facing a total welfare maximizing price ceiling are now as shown in Tab. 4.3.

Statistic	**Value**		
	Price cap	**No interv.**	**Diff.**
Profit maximizing quantity Q	$\frac{57}{110} \approx 0.518$	0.475	(0.043)
Profit maximizing level of R&D investments y	$\frac{19}{55} \approx 0.345$	0.475	0.130
Resulting profit	0.418	0.451	0.033
Consumer welfare	0.403	0.338	0.065
Total welfare	0.820	0.790	0.030

Tab. 4.3: Equilibrium values with optimal price cap

We can conclude from the values in table 4.3 that the total welfare gain that is established by the price cap is due to the combination of a consumer welfare gain and simultaneously a loss of producer surplus, the former slightly outweighing the latter. The total welfare that is established by implementing the price ceiling lays only 3.9% higher than the total welfare generated by the market without intervention. This seems to be only a relatively small improvement, to check how the difference in performance between the price ceiling and the market without intervention varies, we will compare the welfare values in terms of some other values for our parameters. From comparison we find the results displayed in table 4.4.

a	b	c	d	e	**% Gain**	**Note**
2	3	0.1	0	1	3.9%	Standard values
1	3	0.1	0	1	21.5%	$a \downarrow$: Market size smaller
3	3	0.1	0	1	38.8%	$a \uparrow$: Market size greater
2	2	0.1	0	1	0.0%	$b \downarrow$: Slope less steep
2	4	0.1	0	1	8%	$b \uparrow$: Slope steeper
2	3	0.1	0	2	13.6%	$e \uparrow$: R&D More costly
2	3	0.1	0.5	1	10.6%	$d \uparrow$: Increased fixed cost
2	3	0.0001	0	1	3.9%	$c \downarrow$: Decreased variable cost

Tab. 4.4: How outcomes vary with the parameters

From table 4.4 we can see several effects, either increasing or decreasing a can lead to a greater gain from the implementation of a price cap.The effect of b can be seen to support our findings as a steeper slope of the demand in this example leads to a stronger effect of the price cap. In theory, implementation of the price cap can never lead to a decrease in total welfare, as then the optimal price cap would just have to equal the price following from the market without intervention ($\tilde{P} = P^*$). Thus, in the worst case, an implementation of the price cap can lead to a gain of 0%, which is the case when we decrease the steepness of the demand curve to $b = 2$. In our model it could be safe to assume a relatively steep and actually a near perfectly inelastic demand curve, since the orphan drug sector and the pharmaceutical non-lifestyle drug sector is often regarded as very inelastic[9]. Intuitively, the effect of increasing e on the percentage gain from implementing a price cap seems logical. As increasing e creates greater disadvantage of R&D investments might call for an intervention to stimulate R&D even stronger. Implementing a positive value for the fixed costs d other than research investments do not have evident other effects on welfare other than decreasing the absolute values of total welfare, leading to greater relative differences in outcomes. Changing the variable cost c does not affect the outcomes either, as long as it is kept at reasonable levels (it actually behaves well until $c \approx 20$).

Using our standard parameters, we can see that the price cap has led to the monopolist investing less in R&D (about 27.3% less), this is a side effect that the competition authority would rather avoid, as there typically exists underinvestment in R&D from a total welfare standpoint. This can be seen as we maximize total welfare using the variables Q and y, giving us a solution at $\tilde{y} = 1.9$ with $\tilde{Q} = 1.9$, resulting in a total welfare of $TW = 1.805$ which is thus the maximum obtainable total welfare given our initial values.

4.4 Profit Margin Cap

When implementing the profit margin cap, the difficult question is at which percentage the profit margin cap should be set. Say we would introduce a profit margin cap at 30%. The producer then faces the constraint and profit curve shown in figure 4.4.

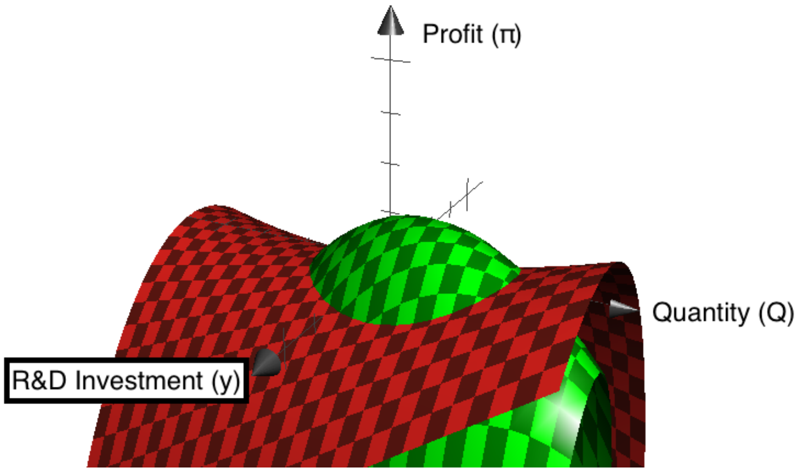

Fig. 4.4: Profit Curve (green) and Constraint (red)

In figure 4.4, on the horizontal axes we have our inputs y and Q. The firm maximizes its profits, which is the variable represented by the vertical axis. The green curve represents the firms' profit curve for given combinations of y and Q while the red curve represents the restriction. For each point on the green curve (profit curve) that lies above the red curve (profit margin restriction), the profit margin exceeds the level of 30%. Each point on the profit curve that lies beneath the restriction, the profit margin falls below 30%. Given that the constraint is binding, which it is when the free market profit maximizing choice of inputs lays within the intersection of the two curves shown above, the firm will now maximize its profits given the possible combinations of the intersection of these two curves, this intersection is an ellipse at our chosen level of the profit margin cap. Given the same initial values for our constants $(a, b, c, d, e) = (2, 3, 0.1, 0, 1)$(from 4.1) and a profit margin cap of $\bar{z} = 0.3$. The situation can now be represented as can be seen in figure 4.5 and figure 4.6. In these figures the x-axis represents quantity and the y-axis represents R&D investments. The blue line is the constraint on the possible combinations for y and Q. The profits are represented on the z-axis. The red dot represents the firms' optimal combination of inputs.

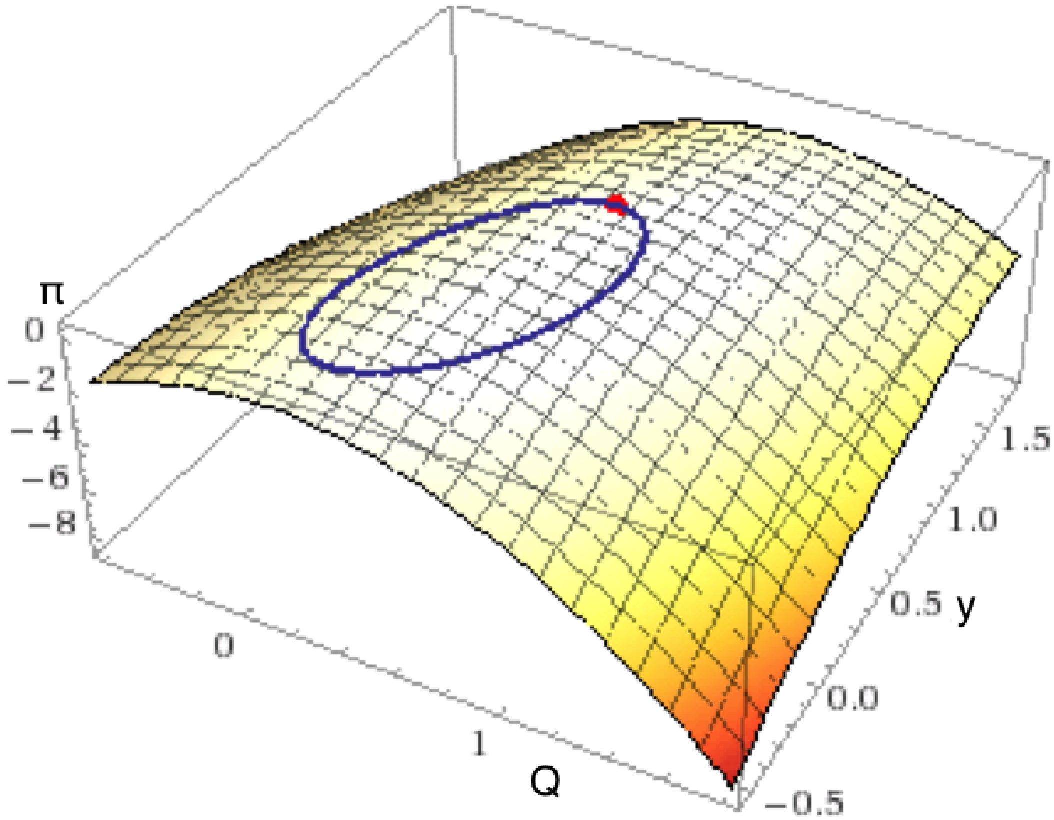

Fig. 4.5: 3D Graph: Optimization of the producer given a profit margin of 0.3 [2]

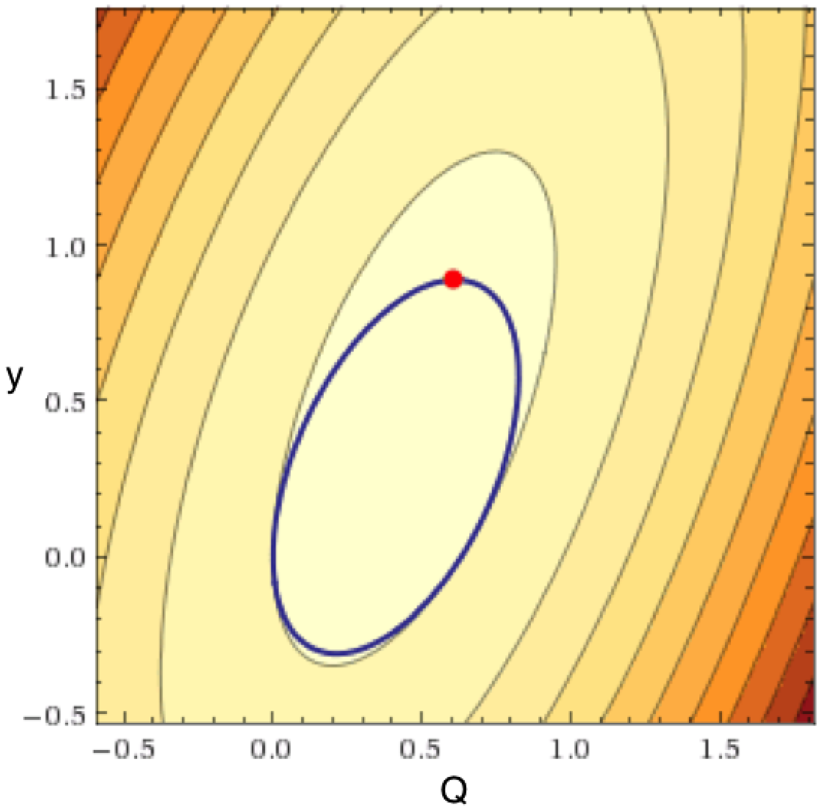

Fig. 4.6: 2D Graph: Optimization of the producer given a profit margin of 0.3 (lighter color = higher value) [2]

The profit maximizing combination of inputs that follows from optimization equals $(y, Q) \approx (0.888, 0.613)$. Resulting in a profit of $\pi = 0.338$ and a consumer welfare of $CW = 0.563$ and thus a total welfare of $TW = 0.901$. Given an arbitrarily chosen profit margin cap, the generated total welfare already exceeds the welfare generated by both the free market as well as the market that faces an optimally chosen price cap.

The profit margin cap cannot be set at a higher level than the resulting profit margin in the market profit maximizing outcome ($\bar{z} \leq 0.623$) in the market without intervention, as it would not be a binding constraint then. We can now plot the values of the total welfare resulting from a profit cap at different levels $\bar{z}$(figure 4.7).

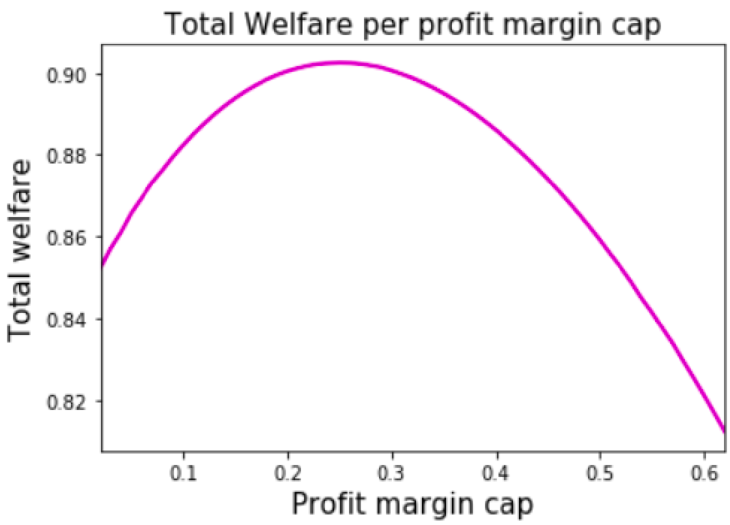

Fig. 4.7: Total Welfare per profit margin cap $(\bar{z})$

After calculation we find that the total welfare maximizing profit cap is 25.1%. Using this profit cap we derive the values that can be found in table 4.5.

Statistic	Value		
	Max. Prof. margin	**Price cap**	**No interv.**
Profit maximizing quantity (Q)	0.633	0.518	0.475
Profit maximizing level of R&D (y)	0.95	0.345	0.475
Resulting profit	0.302	0.418	0.451
Consumer welfare	0.601	0.403	0.338
Total welfare	0.903	0.820	0.790

Tab. 4.5: Equilibrium values with profit margin cap

As can be concluded from table 4.5, the effect of the ideal profit margin cap leads to a total welfare level that lays 14.3% above the total welfare generated by the free market and still 10% beyond the implied maximum total welfare in the case of a price ceiling. This total welfare gain still goes at the cost of the producer (obviously), leading to relatively large consumer welfare gains. We can see that the invested amount in research and development has now moved much closer to the optimal amount $\tilde{y} = 1.9$, as has been derived in the total welfare maximizing case, this was not the case in the situation of a price cap. From the data it can be concluded that the profit margin cap has much more success in creating an incentive to innovate. The price that follows from these values is: $P = 2$, one might wonder whether the combination of a price cap and a profit margin cap might lead to a total welfare amount closer to the socially optimal level of: $TW = 1.805$ (Section 4.1) which too has been derived in the total welfare maximizing case.

4.5 A Combination of Both Interventions

In fact, combining these two constraints may lead to the producer having either one or two possible combinations left. The effect of the constraint of combining both restrictions on possible combinations of inputs is represented in figure 4.8 (we use the values $\bar{P} = \frac{25}{22}$ & $\bar{z} = 0.25$). We have Q on the x-axis and y on the y-axis.

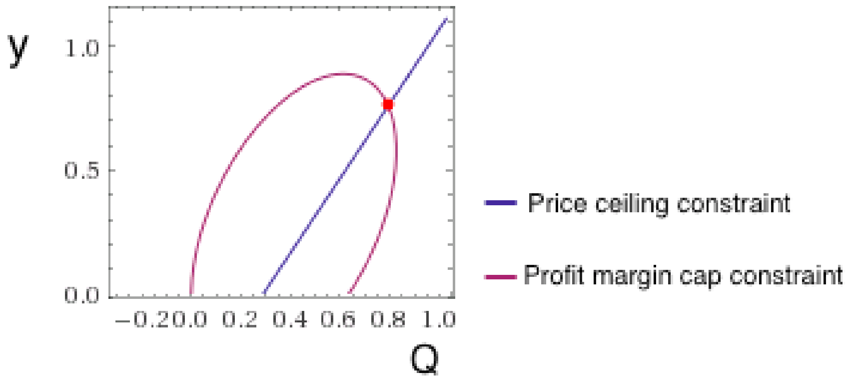

Fig. 4.8: Combining the constraints

We can conclude from figure 4.8 that in this model, setting a combination of a price cap ($\bar{P} = \frac{25}{22}$) and profit margin cap ($\bar{z} = 0.25$) will lead to a single possible combination of inputs if the constraints are binding (which they are). After calculating the intersect of the two constraints we find that this single possible combination of inputs is $(Q, y) = (0.820, 0.798)$.
This combination would lead to a total welfare level of $TW = 1.222$, which is much greater than the total welfare level under any other circumstance that we have investigated other than the necessarily highest possible total welfare generated by the total welfare maximizing firm (Section 4.1). Note that it is not necessarily possible to force the producer to choose total welfare maximizing combination of inputs $\bar{P}$ & $\bar{z}$.

In figure 4.9 we have a 3D-graph showing both constraints. The price cap constraint is shown in red and the profit margin cap is shown in green. The horizontal axes represent Q and y, while the vertical axis represents the values that are set for the restriction.

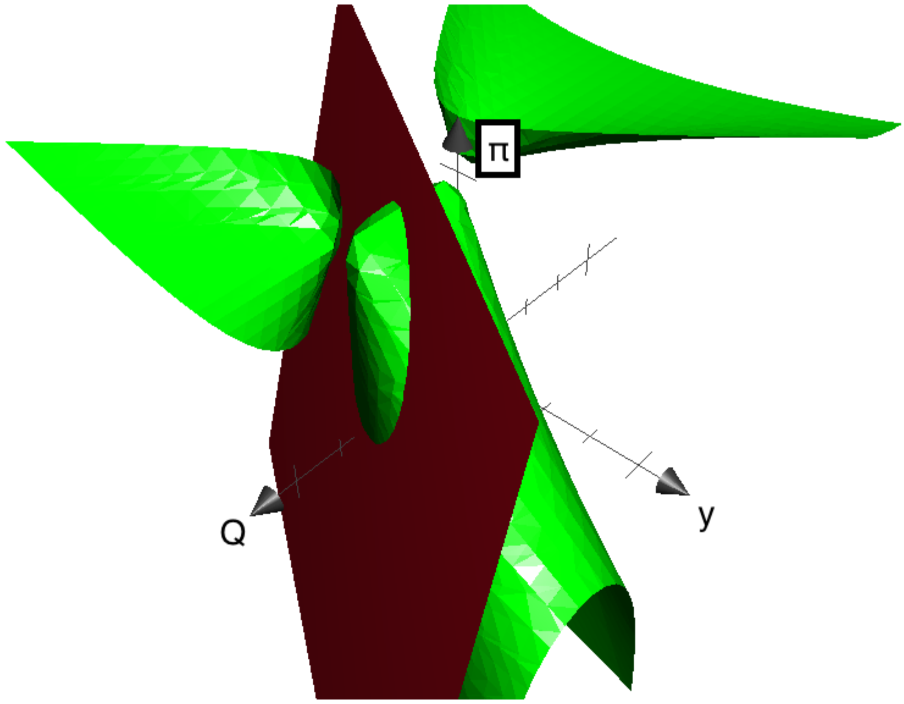

Fig. 4.9: 3D Model of the constraints

The competition authority can most probably not force the producer to choose the total welfare maximizing set of inputs by implementing the restrictions that are the profit margin (loss margin) implied by the total welfare maximizing set of inputs ($\bar{z} = -19$ given $(y, Q) = (1.9, 1.9)$) and the implied price $((\bar{P} = 0.1)$ given $(y, Q) = (1.9, 1.9))$ as these restrictions will most likely not be binding to the producer at the total welfare maximizing combination of inputs, as implementing a negative profit margin cap would force firms to experience losses, a condition under which a firm might decide not to enter the market at all.

5 Conclusion

The market for orphan drugs is increasingly seen as morally dangerous as consumer are predicted to suffer from insurers not being willing to provide orphan drugs since they are increasingly coming with greater costs while they only provide few people. The market for orphan drugs faces conditions that suit monopolistic behavior of firms particularly well. [10]

Several politicians and economists have proposed interventions to tackle the problem of the inefficiencies resulting from monopolistic markets which rely heavily on R&D investment decisions. Wouter Bos [8] proposed to implement a profit margin cap, while other have argued for other types of regulations. Joseph E. Stiglitz [11] has proposed to implement a prize fund. Martin Skhreli [5], the CEO of Turing Pharmaceuticals AG, says that the government should start a pharmaceutical company, selling drugs at cost-price to counter rent-seeking behavior resulting from the presence of orphan drugs.

From our results we can conclude that given this model, combining both a price cap and a profit margin cap leads to the highest total welfare apart from the total welfare maximizing government-owned firm. From this we cannot conclude that the interventions and their performances would behave the same in the model as they would in the real world, however it might give an indication that it can be of great importance to investigate effects on research and development for certain interventions. An estimation of Abbot and Vernon[3] suggested a 30 to 60 percent loss in R&D investment followed from a 40 to 50 percent price cut. This seems to be in line with our results. From the model we may conclude that all total welfare gains from intervening go along relatively large consumer welfare gains and profit losses in this model.

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6 Appendix

In this appendix the derivations of certain equations are provided. The number of the derived equation can be found between parentheses to the right of the equation.

$$P = (1+y)a - bQ$$

$$TC = d + ey^2 + cQ$$

$$[\Pi = \{Q((1+y)a - bQ - c) - d - ey^2]$$

F.O.C.:

$$\Pi'_y = aQ - 2ey = 0 \rightarrow y^*(Q) = \frac{aQ}{2e} \qquad (3.6)$$

$$\Pi'_Q = ((1+y)a - bQ - c) + Q \cdot -b = 0$$

$$2bQ = (1+y)a - c \rightarrow Q^*(y) = \frac{(1+y)a - c}{2b} \qquad (3.7)$$

$$y^* = \frac{a}{2e}\left(\frac{(1+y)a - c}{2b}\right)$$

$$= \frac{(1+y)a^2 - ac}{4be} = \frac{a^2 + ya^2 - ac}{4be}$$

$$4bey - ya^2 = a^2 - ac$$

$$y^* = \frac{a^2 - ac}{4be - a^2} \qquad (3.8)$$

$$Q^* = \frac{\left(1 + \frac{aQ}{2e}\right)a - c}{2b} = \frac{1}{2b}(a-c) + \frac{a^2 Q}{4be}$$

$$4beQ = 2e(a-c) + a^2 Q$$

$$(4be - a^2)Q = 2e(a-c) \longrightarrow Q^* = \frac{2e(a-c)}{4be - a^2} \qquad (3.9)$$

$$\rightarrow P = \left(1 + \left(\frac{a^2 - ac}{4be - a^2}\right)\right)a - b\left(\frac{2e(a-c)}{4be - a^2}\right)$$

$$= a + \left(\frac{a^3 - a^2 c - 2be(a-c)}{4be - a^2}\right)$$

$$P^* = a + \left(\frac{a^3 - a^2 c - 2abe + 2bce}{4be - a^2}\right) \qquad (3.10)$$

$$CW = \left(P(y, Q=0) - P(y, Q)\right) Q \cdot \frac{1}{2}$$

$$CW = \left((1+y)a - (1+y)a - bQ\right) Q \cdot \frac{1}{2}$$

$$= \frac{1}{2} b Q^2$$

$$= \frac{1}{2} b \left(\frac{(a-c)2 \cdot e}{4eb - a^2}\right)^2 \qquad (3.11)$$

$$(3.13) \quad TW(y, Q) = 0.5 b Q^2 + Q\left((1+y)a - bQ - c\right) - ey^2 - d$$

$$FOC: \; TW'_y = aQ - 2ey = 0 \rightarrow \tilde{y}(Q) = \frac{aQ}{2e} \qquad (3.14)$$

$$TW'_Q = bQ + \left((1+y)a - bQ - c\right) - bQ = 0$$

$$(1+y)a - c = bQ$$

$$\tilde{Q}(y) = \frac{(1+y)a - c}{b} \qquad (3.15)$$

$$\tilde{y} = \frac{a}{2be}((1+\tilde{y})a-c) \Rightarrow (a+ay-c)\,a/2be$$

$$y = \frac{a^2-ca}{2be} + \frac{a^2 y}{2be}$$

$$(2be-a^2)y = a^2-ca \rightarrow \tilde{y} = \frac{a(a-c)}{2be-a^2} \quad (3.16)$$

$$\tilde{Q}(\tilde{y}) = \tilde{Q} = \frac{(1+\frac{aQ}{2e})a-c}{b}$$

$$Q = \frac{1}{b}(a + \frac{a^2 Q}{2e} - c) \rightarrow bQ = a + \frac{a^2 Q}{2e} - c$$

$$2be\,Q = 2ea + a^2 Q - 2ce$$

$$(2be-a^2)Q = 2e(a-c) \rightarrow \tilde{Q} = \frac{2e(a-c)}{2be-a^2} \quad (3.17)$$

$$\bar{P} = (1+y)a - bQ \rightarrow Q = \frac{(1+y)a-\bar{P}}{b} \quad (3.18)$$

$$\bar{P} = a + ya - bQ$$

$$y = \frac{\bar{P}+bQ}{a} - 1 \quad (3.19)$$

$$\Pi(y) = (\bar{P}-c)\left(\frac{(1+y)a-\bar{P}}{b}\right) - d - ey^2$$

FOC: $$\Pi'_y = \frac{a}{b}(\bar{P}-c) - 2ey = 0$$

$$y^*_{\bar{P}} = \frac{a}{2be}(\bar{P}-c) \quad (3.21)$$

$$Q^*_{\bar{P}} = \left(\left(1+\left(\frac{a}{2be}(\bar{P}-c)\right)\right)a - \bar{P}\right)\cdot\frac{1}{b} \quad (3.20)$$

$$cw = \frac{1}{2}bQ^2 = \frac{1}{2}\left(\left(1+\left(\frac{a}{2be}(\bar{P}-c)\right)\right)a - \bar{P}\right)^2 \quad (3.22)$$

$$\Pi^*_{\bar{P}} = (\bar{P}-c)Q - ey^2 - d$$

$$\Pi^*_{\bar{P}}(\bar{P}) = \frac{(\bar{P}-c)}{b}\left(\left(1+\frac{a}{2be}(\bar{P}-c)\right)a - \bar{P}\right) - d - e\left(\frac{a^2(P-c)^2}{4e^2b^2}\right) \quad (3.23)$$

*