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PHARMACEUTICAL REGULATION, MANDATORY SUBSTITUTION AND GENERIC COMPETITION

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Pharmaceutical Regulation, Mandatory Substitution, and Generic Competition

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Abstract

This paper studies the effect of two regulatory instruments – a price cap and a reference price system –, a mandatory substitution rule, and the combination of both on generic competition in a Salop-type model with an off-patent brand-name drug and \( n \) differentiated generic versions. The price cap reduces only the brand-name price, the reference price system reduces the brand-name price and generic prices. Both regulatory instruments reduce the generic market share and the number of generic competitors. The mandatory substitution rule decreases the brand-name price, but increases generic prices. It increases the generic market share and the number of generic competitors. Under mandatory substitution, price decreases under both regulatory instruments are lower. Mandatory substitution weakens the negative effect of the price cap on the generic market share and the number of generic competitors, but it amplifies the negative effect of the reference price system on the generic market share and the number of generic competitors.

JEL classification: I18, I11, L50

Keywords: pharmaceutical regulation, generic competition, mandatory substitution, reference price, price cap

1 Introduction

This paper studies the effect of two regulatory instruments – a price cap and a reference price system –, a mandatory substitution rule, and the combination of both on generic competition in a Salop-type model with an off-patent brand-name drug and \( n \) differentiated generic versions.

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This analysis is motivated by potential conflicts between different mechanisms to contain pharmaceutical expenditure, namely, direct regulation of pharmaceutical prices or reimbursement and substitution by lower-priced generics, supported by demand side policies to encourage switching to generics.

In many European countries, the high level of health expenditure has induced a considerable number of government interventions (Maynard, 2003). Supply side instruments are intended to restrict monopoly pricing and reduce the prices of covered services, demand side instruments aim at increasing price sensitivity. Among the great variety of different regulatory instruments, price caps and reference pricing are typical examples for supply side regulation and demand side regulation respectively. Under the price cap, the regulatory body sets a maximum price that can be charged for a drug. The price cap may be based on cost plus a profit margin, prices for the same product in other countries, or prices for therapeutic alternatives (Espin & Rovira, 2007). In the European Union, all countries except the United Kingdom control pharmaceutical prices directly (Kanavos et al., 2011). Under the reference price system, the reference price is the maximum reimbursement for a group of drugs. The group of pharmaceuticals is defined in terms of interchangeability, either with respect to the active ingredient, the therapeutic category, or the therapeutic function (Lopez-Casanovas & Puig-Junoy, 2000). Firms remain free to charge higher prices. If the manufacturer’s price exceeds the reference price, the patient has to pay the difference between the market price and the reference price him/herself (Danzon, 2001). That is, the reference price system involves an additional, but avoidable co-payment (Lopez-Casasnovas & Puig-Junoy, 2000). In the European Union, among others Austria, Belgium, Finland, France, Germany, Italy, Netherlands, Portugal, and Spain use reference price systems (EGA, 2011).

In addition to influencing pharmaceutical prices directly, the substitution of higher-priced brand-name drugs by less expensive equivalents has been promoted, most notably generics, chemically identical drugs with the same active ingredient. Generics are priced 20%-80% lower than brand-name drugs and may contribute to substantial savings (Simoens & De Coster, 2006).

Generic market shares fall short of expectations, as prescription decisions in favor brand-name drugs (and against generics) might be determined rather by physician habit or time dependence than by observable patient characteristics (Hellerstein, 1998, Coscelli, 2000), pharmacists may be more likely to dispense brand-name drugs depending on relative margins (Brekke, Holmas & Straume, 2013), and consumers may prefer brand-name drugs because of brand-loyalty or familiarization (Frank & Salkever, 1992). Generics may also be perceived as of lower quality (see Gaither et al. (2001) for a sur-
vey of consumers’ view of generics), e.g., if the lower price is interpreted as a quality indicator (Waber et al., 2008).

Consequently, many European countries have implemented demand side policies to promote generic substitution (Simoens & De Coster, 2006; Kanavos, Costa-Font & Seeley, 2008). Physicians should be encouraged to prescribe generics by budgetary restrictions or budgetary incentives, applying in France, Germany, Italy, Spain, and the United Kingdom (EGA, 2011). Also prescribing by international nonproprietary name (INN), which is encouraged in Belgium, Germany, the Netherlands, and the United Kingdom and mandatory in France, Portugal, and Spain, aims at increasing generic market shares (EGA, 2011). For pharmacists, generic substitution is compulsory in Finland, France, Germany, Norway, Spain, and Sweden (EGA 2011). Higher margins for generics than for brand-name drugs, making generic substitution also financially attractive, exist only in the United Kingdom (Simoens & De Coster, 2006). But also in most countries margins for generics are not lower than for brand-name drugs, except in Sweden (EGA, 2011).

Substitution policies may reduce expenditure through two channels: First, they foster the substitution by lower priced generics, second, they may intensify price competition. Granlund (2010) finds that the Swedish substitution has reduced drug prices by 10% on average, with price reductions for brand-names being higher than for generics. For the Finnish substitution reform, Aalto-Setälä (2008) shows that average prices decreased by more than 10%. He also concludes that price changes were uneven: While some prices decreased substantially, other prices increased. Granlund & Rudholm (2011) suggests that the Swedish substitution reform has reduced brand-name and generic drug prices by increasing patient information on prices and thus enhancing competition. Hokkanen et al. (2012) argue that Finnish substitution reform has decreased prices by making firms change their pricing strategy for existing products in the market rather than by inducing firms to introduce new products. Granlund & Köksal-Ayhan (2014) conclude that the Swedish substitution reform increased the effect of therapeutic competition more than the effect of competition by parallel imports.

However, these two approaches—promoting generic competition and regulating prices or reimbursement directly—may conflict. Pharmaceutical regulation per se may exhibit

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1Substitution can be prevented by physicians by ticking a box (France, Germany) or writings (Netherlands, Norway) (EGA, 2011)
a trend of inhibiting competition by reducing generic entry. Danzon (2000) finds that
generic competition is stronger in countries with no regulation or weak regulation (USA,
Germany, the United Kingdom, or Canada) than in those with a high degree of regulation
(France, Italy, or Japan). Also Simoens & De Coster (2006) suggest that price regulation
lowers brand-name prices, thus lowering the potential profit margin for a generic and
discouraging market entry. Costa-Font, McGuire & Varol (2014) show that higher levels
of price regulation (in some countries) may lead c.p. to greater delays in generic entries
by lowering the expected price to generic manufacturers. Kanavos, Costa-Font & Seeley
(2008) also argue that regulation for patent protected drugs may inhibit the extent
to which generics are price competitive, while free pricing for patent protected drugs
may contribute to generic competition with an aggressive pricing approach. Thus, the
impact on generic competition may depend on the regulatory instrument. Reference
price systems, which involve free pricing, may increase generic market shares (Aronsson,
Bergman & Rudholm, 2001; Pavcnik, 2002, Dalen, Strøm & Haabeth, 2006; Brekke,
pricing may shift market shares from the brand-names to the generics (for 3 out of
12 different substances studied). Dalen, Strøm & Haabeth (2006) conclude that the
reference price system in Norway has increased the market shares of generic drugs and
reduced overall market power. Brekke; Holmas & Straume (2011) compare price cap
regulation with reference pricing and find that reference pricing induces stronger generic
competition, while price cap regulation reduces the generic market share. A study by
the European Commission, which analyzes the prices of 122 active ingredients in 17 EU
countries between 2000 and 2007, also concludes that price cap regulation affects price
competition negatively (EU Commission, 2009).

A second conflict may come from the potential overlap of different regulatory in-
struments, when instruments of direct price regulation and policies promoting generic
competition may enforce or impede each other. Bardey, Jullien & Lozachmeur (2013)
show that a copayment policy and reference pricing may be complements. Similarly,
Grandlund (2010) suggests that the Swedish substitution reform amplified the effect of
generic entry on brand-name prices substantially.

Against this background, this paper studies the effect of two regulatory instruments
– a price cap and a reference price system –, a mandatory substitution rule, and the
combination of both on generic competition. Following Madden & Pezzino (2011), it
assumes a market for an active ingredient, where consumers are located on the circum-
ference of a Salop circle and may choose between an off-patent brand-name version of the
drug (center of the circle) and one of \( n \) horizontally differentiated generic versions (on
the circumference). This allows considering two dimensions of generic competition, the
generic market share and the number of generic competitors. While both generic market
shares and the number of generic competitors determine the degree of generic compe-
tition and corresponding savings, the number of generic competitors may also provide
an indication of mismatch cost, if substitutability of generics is limited. Moreover, the
consideration of both aspects allows assessing market shares per firm and thus generic
concentration. The Salop framework assumes inelastic demand and no changes in total
quantity demanded. This suggests that market size does not depend on the price, but
rather on prevalence of a specific disease.

The price cap reduces only the brand-name price, the reference price system reduces
the brand-name price and generic prices. Both regulatory instruments reduce the generic
market share as well as the number of generic competitors. The mandatory substitution
rule decreases the brand-name price, but increases generic prices. It increases the generic
market share and the number of generic competitors. Under mandatory substitution,
price decreases under both regulatory instruments are lower. Mandatory substitution
weakens the negative effect of price cap on the generic market share and the number of
generic competitors, but it amplifies the negative effect of the reference price system on
the generic market share and the number of generic competitors.

The rest of the paper is organized as follows. The next section presents the model.
Section 3 analyzes the scenarios of no pharmaceutical regulation, a price cap, and a
reference price system. Section 4 studies welfare. Section 5 concludes.

2 The Model

Consider a market for an active ingredient with a off-patent brand-name drug $b$ and
$n > 1$ corresponding, differentiated generic versions $g(i)$. Following Madden & Pezzino
(2011), the firms offering the differentiated generic versions $g(i)$ are located equidistantly
around the perimeter of a unit circle, the firm providing the brand-name drug is located
in the center of the circle.

Patients are also located around the perimeter of the circle. Based on their location,
they have a preference for one of the generic versions due to differences in excipients
(binders, coating, fillers etc.) or bioavailability, previous intake or different packaging.
Patients incur mismatch cost for deviations from the ideal version. All patients have the

\[ \text{Bioequivalence allows for peak concentration a 90%-confidence interval between 80%-125%}. \] Sub-
stitution is limited or impossible for critical dose drugs, which are characterized by narrow therapeutic
ranges, serious consequences of under-/overdoses and/or the need for individual doses.
same distance to the center, the mismatch cost for the brand-name is thus independent of the patients’ location. This mismatch is normalized to zero.

Health insurance reimburses a fraction of the drug price, the remaining fraction $\gamma$ is paid by the patient.

The utility of a patient who is located at $x$ and buys the brand-name version $b$ located at the center, is given by

$$U = v - \gamma p_b,$$ (1)

where $v$ denotes the gross utility from consumption, $\gamma$ is the coinsurance rate and $p_b$ is the price of the brand-name version $b$.

The utility of a patient who is located at $x$ and buys a generic version $g(i)$ located at $z_i$, is given by

$$U = v - t |x - z_i| - \gamma p_{g(i)},$$ (2)

where $t$ denotes mismatch cost for deviations of the product’s attributes from the patients’ preferences, and $p_{g(i)}$ is the price of generic version $g(i)$.

**Mandatory Substitution** Assume that a fraction $\lambda$ of patients is subject to mandatory generic substitution rule (denoted as G-type). These patients receive generic prescriptions from physicians or are dispensed a generic substitute from the pharmacist, if they have brand-name prescription. Consequently, these patients may still choose freely, but only among the generic versions. The remaining fraction $1 - \lambda$ is not constrained its drug choice (denoted as B-type).\(^3\) Both types are uniformly distributed on the perimeter of the circle. The share $\lambda$ is constant at each point on the perimeter. Assume $\lambda \leq \lambda^* = \frac{2}{3}$ for the brand-name price to be higher than the generic prices under no regulation. In that case, market power of the brand-name drug to be sufficiently high to justify pharmaceutical price regulation targeting primarily the brand-name.

Production technologies exhibit constant marginal costs, which are normalized to zero. Profits are given as

$$\pi_b = p_b q_b, \pi_{g(i)} = p_{g(i)} q_{g(i)} - f.$$ (3)

Assume sufficiently low cost of market entry for the generic firms, i.e. $f < f^* = \frac{t}{18\gamma}$ under no mandatory substitution and $f < f^* = \frac{t(2-\lambda)(\lambda+1)^2}{4\gamma(3-2\lambda)^2}$ under mandatory substitution, for more than one firm to be active in the market and thus an oligopoly market

\(^3\)Alternatively, assume that all patients are subject to a mandatory substitution rule, but that B-type can refuse substitution, while G-types cannot.
structure.

The structure of the model can be summarized by the following two-stage game: In the first stage, potential generic competitors simultaneously decide whether to enter the market for an active ingredient at fixed cost of entry $f$, where a brand-name producer is already active. The generic firms entering are located equidistantly around the circle. In the second stage, firms compete in prices.

\section{3 Regulatory Scenarios}

\subsection{3.1 No Regulation}

\subsubsection{3.1.1 No Mandatory Substitution}

Consider first the case without regulation as a benchmark. The marginal patient, indifferent between purchasing the closest generic version $i$ and the brand-name drug $b$, is given by $v - \gamma p_b = v - tx - \gamma p_g$, which yields $x = \frac{\gamma(p_b - p_g)}{f}$. Demand for the brand-name is given by $q_b = 1 - n2x$, demand for the generic version $i$ is given by $q_{g(i)} = 2x$.

The number of entering firms is determined by the zero-profit condition:

\begin{equation}
    n = \frac{\sqrt{2f}}{6\sqrt{f\gamma}}.
\end{equation}

Equilibrium drug prices are

\begin{equation}
    p_b = \frac{2\sqrt{ft}}{\sqrt{2\gamma}}, \quad p_g = \frac{\sqrt{ft}}{\sqrt{2\gamma}}.
\end{equation}

Equilibrium quantities are

\begin{equation}
    q_b = \frac{2}{3}, \quad q_g = \frac{2\sqrt{ft\gamma}}{\sqrt{2t}}.
\end{equation}

The generic market share is

\begin{equation}
    Q_g = nq_g = \frac{1}{3}.
\end{equation}

As in the standard Salop model, higher fixed cost of market entry decrease the number of firms, increase both prices and increase the quantity sold per firm. Higher mismatch cost increase the number of firms, increase both prices and decrease the quantity sold per firm. An increase in the coinsurance rate, i.e. a reduction of the reimbursed amount and an increase of the copayment, decreases the number of firms, decreases both prices
and increases the quantity sold per firm. Market shares are not affected by changes in fixed cost, mismatch cost or the coinsurance rate.

### 3.1.2 Mandatory Substitution

Consider now the case where a fraction $\lambda$ of patients is subject to a mandatory substitution rule. A subscript $\lambda$ is used to denote variables under mandatory substitution.

The marginal $B$-type patient $x_B$ is identical to the marginal patient $x$ under no mandatory substitution. The marginal $G$-type patient, indifferent between purchasing the generic version $g_i$ and the generic version $g_j$, is given by $v - t x_G - \gamma p_{g(i)} = v - t \left( \frac{1}{\beta} - x_G \right) - \gamma p_{g(j)}$, which yields $x_G = \frac{1}{2t} + \frac{\gamma (p_{g(j)} - p_{g(i)})}{2t}$. Demand for the brand-name is given by $q_B = (1 - \lambda) (1 - n 2 x_B)$. Demand for the generic version $i$ is given as $q_{g(i)} = (1 - \lambda) 2 x_B + \lambda 2 x_G$.

The number of entering firms is determined by the zero-profit condition:

$$n_\lambda = \frac{(1 + \lambda) \sqrt{t (2 - \lambda)}}{2 (3 - 2 \lambda) \sqrt{f \gamma}}. \tag{7}$$

First stage equilibrium drug prices are

$$p_{b,\lambda} = \frac{(4 - \lambda) \sqrt{ft}}{2 (1 + \lambda) \sqrt{\gamma (2 - \lambda)}}, \quad p_{g,\lambda} = \frac{\sqrt{ft}}{\sqrt{\gamma (2 - \lambda)}}. \tag{8}$$

Equilibrium quantities are

$$q_{b,\lambda} = \frac{(1 - \lambda) (4 - \lambda)}{2 (3 - 2 \lambda)}, \quad q_{g,\lambda} = \frac{\sqrt{f \gamma (2 - \lambda)}}{\sqrt{t}}. \tag{9}$$

The generic market share is

$$Q_{g,\lambda} = n q_g = \frac{(\lambda + 1) (2 - \lambda)}{2 (3 - 2 \lambda)}. \tag{9}$$

Generic substitution increases demand for the generic versions for given prices, increasing the generic market share and - due to higher profits of generic firms - also the number of firms. Both a higher generic market share and a higher number of firms can be interpreted as stronger generic competition. Under no mandatory substitution, generic firms compete with the brand-name producer for the complete market. Under mandatory substitution, generic firms compete with the brand-name producer only for the share $\lambda$ of the market, while they compete with other generic firms for the remaining
share $1 - \lambda$ of the market. Accordingly, this decreases the response of the generic price to the (higher) brand-name price, but adds the response to other (lower) generic prices, also enhancing generic competition. On the contrary, higher demand for generics induces generic firms to increase prices ($p_{g,\lambda} > p_g$). Both the higher price and the higher number of firms reduce the quantity for a single generic version ($q_{g,\lambda} < q_g$).

At the same time, generic substitution decreases demand for the brand-name. This makes the brand-name producer lower the price for the brand-name ($p_{b,\lambda} < p_b$), but he is unable to compensate the loss in demand and the quantity of the brand-name decreases ($q_{b,\lambda} < q_b$). A higher fraction of patients subject to the mandatory substitution rule amplifies these effects of mandatory substitution. The generic market share and the number of firms increase under mandatory substitution ($n_\lambda > n, Q_{g,\lambda} > Q_g$).

Proposition 1 summarizes the effect of a mandatory substitution rule:

**Proposition 1** A mandatory substitution rule i) decreases the brand-name price, increases the generic price, ii) increases the number of firms, and iii) shifts demand from the brand-name to the generic versions, while reducing the generic concentration.

### 3.2 Price Cap

#### 3.2.1 No Mandatory Substitution

Now assume a price cap $P$, which is binding for the brand-name drug, but not the generic. The regulator sets a maximum price equal to the price of the generic plus a markup. The price cap

$$P = p_g + (1 - m)(p_b - p_g) = \frac{(2 - m)\sqrt{F}}{\sqrt{2}}$$

(10)

corresponds to the generic price in the no regulation case ($p_g$) plus a fraction $(1 - m)$, with $m \in (0, 1)$ of the brand-name markup ($p_b - p_g$). The case of $m = 0$ corresponds to no regulation (the brand-name producer is not constrained in setting a price), while the case of $m = 1$ corresponds to the strictest regulation possible (the price of the brand-name drug is set to the price of the generic). Thus, the regulatory parameter $m$ is a measure for the strictness of regulation.
Equilibrium drug prices are given as

\[
\begin{align*}
    p_b^m &= P = \frac{(2 - m) \sqrt{ft}}{\sqrt{2\gamma}}, \\
    p_g^m &= \frac{1}{2} P = \frac{(2 - m) \sqrt{ft}}{2\sqrt{2\gamma}}.
\end{align*}
\]  

(11)

Under the price cap, there is no explicit solution for \( n \), the number of firms, as competition has no global dimension and is only local. The generic price is given by the optimal response to the brand-name price. Under no regulation, the brand-name price depends on the number of generic competitors, but under the price cap, it is fixed by the regulator. Consequently, there is no effect of the number of generic competitors on the generic price and the profit of a generic producer is independent on \( n \). The brand-name profit, however, decreases in \( n \), but the brand-name producer cannot respond to changes in \( n \) under the price cap.

Under no regulation, a higher number of generic competitors decreases the profit of the brand-name producer, who in turn lowers the price. This makes the generic producers decrease the generic price, which lowers the profit of generic producers and decreases the number of firms active. Under the price cap, there is no price reaction of the brand-name producer to the number of generic firms.\(^4\)

Equilibrium quantities are

\[
\begin{align*}
    q_b^m &= 1 - \frac{n\sqrt{2ft\gamma}(2 - m)}{2t}, \\
    q_g^m &= \frac{\sqrt{2ft\gamma}(2 - m)}{2\sqrt{t}}.
\end{align*}
\]  

(12)

The generic market share is

\[
Q_g^m = nq_g^m = \frac{n\sqrt{2ft\gamma}(2 - m)}{2t}.
\]  

(13)

By construction, the price cap lowers the brand-name price \((p_b^m < p_b)\), which in turn lowers the generic price by strategic response of the generic firms \((p_g^m < p_g)\). The quantity sold by a single generic firm decreases \((q_g^m < q_g)\). For a sufficiently high number of firms, \( n^m > \tilde{n}^m = \frac{\sqrt{2\gamma}}{3(2 - m)\sqrt{ft\gamma}} \), \( \tilde{n}^m > n \), the price cap does not decrease the generic

\(^4\)If the number of generics is sufficiently high, the brand-name producer lowers his price below the price cap, and, according to the mechanism described above, less generic firms enter the market and the brand-name producer raises his price again. A brand-name price below the price cap cannot be an equilibrium.
market share or even increases it. If the number of firms is the same as under no regulation \( n^m = n \), however, the price cap shifts demand from the generics to the brand-name drug.

### 3.2.2 Mandatory Substitution

Under mandatory substitution, the number of firms is

\[
n_{\lambda}^m = \frac{(\lambda + 1) \lambda \sqrt{(2 - \lambda)t}}{(m (2 - 3\lambda) (1 - \lambda) + 2\lambda (3 - 2\lambda)) \sqrt{\gamma}}.
\]  

Equilibrium drug prices are

\[
\begin{align*}
p_{b,\lambda}^m &= \frac{(4 - \lambda - m (2 - 3\lambda)) \sqrt{ft}}{2 (\lambda + 1) \sqrt{\gamma (2 - \lambda)}} \\
p_{g,\lambda}^m &= \frac{\sqrt{ft}}{\sqrt{\gamma (2 - \lambda)}}.
\end{align*}
\]  

The equilibrium quantities are

\[
\begin{align*}
q_{b,\lambda}^m &= \frac{(1 - \lambda) ((4 - \lambda) \lambda + m (2 - 3\lambda))}{m (2 - 3\lambda) (1 - \lambda) + 2\lambda (3 - 2\lambda)} \\
q_{g,\lambda}^m &= \frac{\sqrt{f\gamma (2 - \lambda)}}{\sqrt{t}}.
\end{align*}
\]  

The generic market share is

\[
Q_{g,\lambda}^m = \frac{\lambda (\lambda + 1) (2 - \lambda)}{m (2 - 3\lambda) (1 - \lambda) + 2\lambda (3 - 2\lambda)}.
\]

The combination of the two instruments affects how they work: First, under the price cap, the effect of the mandatory substitution rule is partly different than under no regulation. Under the price cap, mandatory substitution may increase or decrease the brand-name price, depending on the degree of regulation \( p_{b,\lambda}^m > p_b^m \), if \( m < m^* \), while under no regulation, it decreases the brand-name price. The effect of mandatory substitution on the generic price and the quantity sold by a single generic firm is the same under no regulation and the price cap \( p_{g,\lambda}^m > p_g^m \), \( q_{g,\lambda}^m < q_g^m \). Second, the effect of the price cap is partly different under mandatory substitution than under no mandatory substitution. Under mandatory substitution, the price cap reduces the brand-name price, but leaves the generic price unchanged \( p_{b,\lambda}^m < p_b, p_{g,\lambda}^m = p_g, \lambda \), whereas under no mandatory substitution, it reduces both prices. Similarly, under mandatory substitution,
the price cap does not change the quantity sold by a single generic firm \((q^m_g = q_{g,\lambda})\).

Under mandatory substitution, the price cap reduces the number of firms \((n^m_\lambda < n_\lambda)\) and shifts demand from the generic versions to the brand-name \((Q^m_{g,\lambda} < Q_{g,\lambda}, q^m_{b,\lambda} > q_{b,\lambda})\).

For the joint effect of the price cap and the mandatory substitution rule, consider the change in prices, quantities, the number of firms between price cap and no regulation under no mandatory substitution and mandatory substitution. For the variables that could not be derived explicitly under the price cap and no mandatory substitution, consider the change in the variable with an increasing share of patients subject to the mandatory substitution rule. Under generic substitution, both price decreases are lower \((|p^m_b - p_b| > |p^m_{g,\lambda} - p_{g,\lambda}|, |p^m_g - p_g| > p^m_{g,\lambda} = p_{g,\lambda})\) and the decrease in the quantity sold by a single generic firm is lower \((|q^m_g - q_g| > q^m_{g,\lambda} = q_{g,\lambda})\). A higher share of patients subject to generic substitution weakens the firm-decreasing and market-share shifting effect \((\frac{\partial(n^m_\lambda - n_\lambda)}{\partial \lambda} < 0, \frac{\partial(Q^m_{g,\lambda} - Q_{g,\lambda})}{\partial \lambda} < 0, \frac{\partial(q^m_{g,\lambda} - q_{g,\lambda})}{\partial \lambda} < 0)\).

Proposition 2 summarizes the effect of the price cap under mandatory substitution.

**Proposition 2**  
Price cap regulation i) reduces the brand-name price, but does not change the generic price, ii) reduces the number of generic firms, iii) shifts demand from the generic to the brand-name drug. Generic substitution lowers price decreases and a higher share of patients subject to mandatory substitution weakens the number of firm-decreasing effect and the generic market share-reducing effect of the price cap.

### 3.3 Reference Price

#### 3.3.1 No Mandatory Substitution

Consider now a reference price system, where the reference price is the reimbursement limit for both the brand-name and the generics. Firms remain free to charge higher prices. If a patient wishes to purchase a drug, which is priced above the reference price, he/she has to pay the difference between the market price of the drug and the reference price in addition to the usual copayment. The reference price is a linear function of both drug prices

\[
R = rp^*_g + (1 - r)p^*_b
\]

where \(r \in (0, 1)\) is an exogenous weight. For \(r = 1\), the reference price and consequently the reimbursement amount corresponds to the price of the generic, for \(r = 0\), the reference price and reimbursement amount coincide with the price of the brand-name drug, which amounts to the benchmark case of no regulation. The reference price is determined endogenously, which involves a reaction of the reference price to the firms’ strategic

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response to the introduction of a reference price system. Note that a generic version is available without an additional co-payment.

The marginal patient is now given by

\[ v = \frac{p_b - p_g}{r(1-\gamma) + \gamma}. \]

The number of firms is

\[ n^r = \frac{\sqrt{2t}}{6\sqrt{f(r(1-\gamma) + \gamma)}}. \tag{18} \]

Equilibrium prices are given as

\[ p^r_b = \frac{2\sqrt{ft}}{\sqrt{2(r(1-\gamma) + \gamma)}}, \quad p^r_g = \frac{\sqrt{ft}}{\sqrt{2(r(1-\gamma) + \gamma)}}. \]

Equilibrium quantities are

\[ q^r_b = \frac{2}{3}, \quad q^r_g = \frac{\sqrt{f^2(r(1-\gamma) + \gamma)}}{\sqrt{t}}. \tag{19} \]

The generic market share is

\[ Q^r_g = n q^r_g = \frac{1}{3}. \tag{20} \]

Under the reference price system, both drug prices are lower than under no regulation, as reimbursement is limited \((p^r_b < p_b, p^r_g < p_g)\). The number of firms is lower \((n^r < n)\), market shares are not affected \((q^r_b = q_b, Q^r_g = Q_g)\), while the quantity for a single generic version increases \((q^r_g > q_g)\).

### 3.3.2 Mandatory Substitution

The marginal \(B\)-type patient \(x_B\) is identical to the marginal patient \(x\) under no mandatory substitution. The marginal \(G\)-type is not affected by the additional copayment.

The number of firms is

\[ n^r_\lambda = \frac{(\lambda + 1) \sqrt{f(\gamma (2-\lambda) + 2r(1-\gamma)(1-\lambda))}}{2\sqrt{f(3r(1-\gamma)(1-\lambda) + \gamma(3-2\lambda))}}. \tag{21} \]
First stage equilibrium drug prices are given as

\[
p_{r,b}^\lambda = \frac{(\gamma (4 - \lambda) + 2r (1 - \gamma) (2 - \lambda)) \sqrt{f}}{2 \sqrt{(\gamma (2 - \lambda) + 2r (1 - \gamma) (1 - \lambda) (\lambda + 1) (r (1 - \gamma) + \gamma))}},
\]

\[
p_{r,g}^\lambda = \frac{\sqrt{f}}{\sqrt{(\gamma (2 - \lambda) + 2r (1 - \gamma) (1 - \lambda))}}.
\]

Equilibrium quantities are

\[
q_{r,b}^\lambda = \frac{(1 - \lambda) (\gamma (4 - \lambda) + 2r (1 - \gamma) (2 - \lambda))}{2\gamma (3 - 2\lambda) + 6r (1 - \gamma) (1 - \lambda)},
\]

\[
q_{r,g}^\lambda = \frac{\sqrt{f} (\gamma (2 - \lambda) + 2r (1 - \gamma) (1 - \lambda))}{\sqrt{f}}.
\]

The generic market share is

\[
Q_{r,g}^\lambda = \frac{(1 + \lambda) (\gamma (2 - \lambda) + 2r (1 - \gamma) (1 - \lambda))}{2\gamma (3 - 2\lambda) + 6r (1 - \gamma) (1 - \lambda)}.
\]

Again, the two instruments work differently if they are applied in combination than if they are applied separately.

Under the reference price system, mandatory substitution has the same effect as under no regulation. It increases the number of firms ($n_{r,b}^\lambda > n^r$). It decreases the brand-name price ($p_{r,b}^\lambda < p_b$) and increases the generic price ($p_{r,g}^\lambda > p_g$). It decreases the brand-name quantity and the quantity for a single generic firm ($q_{r,b}^\lambda < q_b$, $q_{r,g}^\lambda < q_g$) and increases the generic market share ($Q_{r,g}^\lambda > Q_g$).

The effect of the reference price system is partly different under mandatory substitution than under no mandatory substitution. Under both no mandatory substitution and mandatory substitution, the reference price system reduces the number of firms and both prices ($n^r < n$, $n_{r,b}^\lambda < n_{r,b}$, $p_{r,b}^\lambda < p_{r,b}$, $p_{r,g}^\lambda < p_{r,g}$, $p_g < p_g$, $p_{r,g}^\lambda < p_{r,g}$). But whereas under no mandatory substitution, the reference price system does no change market shares ($q_b^r = q_b$, $Q_g^r = Q_g$), under mandatory substitution, the reference price system increases the brand-name quantity and decreases the generic market share ($q_{r,b}^\lambda > q_b$, $Q_{r,g}^\lambda < Q_g$).

For the joint effect of the reference price system and the mandatory substitution rule, consider the change in prices, quantities, the number of firms between price cap and no regulation under no mandatory substitution and mandatory substitution. Under generic substitution, both price decreases are lower ($|p_{r,b}^\lambda - p_{r,b}| > |p_{r,b}^\lambda - p_b|$, $|p_{r,g}^\lambda - p_g| > |p_{r,g}^\lambda - p_{r,g}|$) and the increase in the quantity sold by a single generic firm is lower.
$(q_g^r - q_g > q_{g,\lambda}^r - q_{g,\lambda})$. Under mandatory substitution, the decrease in firms is higher $(|n^r - n| < |n_{\lambda}^r - n_{\lambda}|)$ and a shift of demand from the generics to the brand-name occurs.

**Proposition 3** The reference price system i) reduces the brand-name price and generic price, ii) reduces the number of generic firms, iii) shifts demand from the generic to the brand-name drug. Generic substitution i) lowers price decreases and ii) amplifies the number of firm-decreasing effect and the generic market share-reducing effect of the reference price system.

4 Welfare

As in the standard Salop model, price changes do not affect the quantity and welfare, as demand is inelastic. Maximizing welfare is equivalent to minimizing the sum of mismatch cost and market entry cost. This section studies mismatch cost, i.e. welfare under the regulatory scenarios.

4.1 No Mandatory Substitution

Consider first the case of no mandatory substitution. Under no regulation, the sum of mismatch cost and entry cost is given as

$$C = 2nt \int_0^\infty sds + nf = \frac{\sqrt{2t (\gamma + 2)}}{12 \sqrt{\gamma}}.$$  

Under the price cap, there is no explicit expression for mismatch cost, as there is no explicit solution for the number of firms.

Under the reference price, the sum of mismatch cost and entry cost is given as

$$C^r = \frac{\sqrt{2fr (2 + (r (1 - \gamma) + \gamma))}}{12 \sqrt{(r (1 - \gamma) + \gamma)}}.$$  \hspace{1cm} (25)

The sum of mismatch cost and entry cost is lower, i.e. welfare is higher than under no regulation ($C^r < C$).
4.2 Mandatory Substitution

Consider now the case of a mandatory substitution rule. Under no regulation, the sum of mismatch cost and entry cost is given as

\[ C_\lambda = \frac{\sqrt{f_y t (2 - \lambda)} \left( 4 (\gamma + 2) + \lambda \left( 20 \gamma - 4 \lambda^2 - 27 \lambda \gamma + 7 \lambda^2 \gamma + 12 \right) \right)}{8 \gamma (2 - \lambda) (3 - 2 \lambda) (\lambda + 1)}. \]  

(26)

The sum of mismatch cost and entry cost is higher, i.e. welfare is lower than without the mandatory substitution rule \((C_\lambda > C)\).

Under the price cap, the sum of mismatch cost and entry cost is given as \(C^m_\lambda\), which is lower than under no regulation \((C^m_\lambda < C_\lambda)\).

Under the reference price, the sum of mismatch cost and entry cost is given as \(C^r_\lambda\), which is lower than under no regulation \((C^r_\lambda < C_\lambda)\).

Proposition 4 summarizes the welfare effects of regulation.

**Proposition 4** Both regulatory instruments increase welfare, mandatory substitution decreases welfare.

5 Conclusion

This paper studies the effect of two regulatory instruments – a price cap and a reference price system –, a mandatory substitution rule, and the combination of both on generic competition in a Salop-type model an off-patent brand-name drug and \(n\) differentiated generic versions.

The two regulatory instruments reduce the brand-name drug price. In addition, the reference price system reduces generic prices, the price cap only if applied in combination with the mandatory substitution rule. On the downside, both regulatory instruments reduce the generic market share and the number of generic competitors. This suggests that there may be a conflict between price reductions and generic competition. This also applies to the mandatory substitution rule. It increases the generic market share and the number of generic competitors, but decreases only the brand-name price, while increasing generic prices. If applied in combination, the regulatory instruments and the mandatory substitution rule may enforce or impede each other. Both regulatory instruments result in lower price decreases under the mandatory substitution rule. Mandatory substitution weakens the negative effect of the price cap on generic competition, but it amplifies the negative effect of the reference price system on generic competition.
The separate and the combined effect of the regulatory instruments and the mandatory substitution rule suggest that policy makers face a trade-off between (short-term) price reductions and generic competition. Lower drug prices may reduce copayments and public expenditure in the short run, whereas in the long run, the decline in generic competition may result in higher prices (as compared to prices with stronger competition) and higher mismatch cost, if the substitutability between the brand-name drug and the generics is limited. Conversely, a substitution rule may foster generic competition, but it comes at the price at higher generic prices, accordingly higher copayments and health expenditure. The combination of instruments may mitigate the conflict between price reductions and impeding generic competition. If both a price cap and a substitution rule - a supply side and a demand side instrument - are applied, price decreases and generic competition is reduced, but both not as much as without the substitution rule. Conversely, the combination of the reference price system and mandatory substitution - two demand side instruments - also weakens price decreases, but at the same time amplifies the decline in generic competition. This suggests that the application of more than one instrument is not per se a problem, but that rather the specific combination of instruments is important. The combination of instruments that target different sides of the market seems to work better than the combination of instruments, which address the same market side.
References


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Appendix

No Regulation

\[ n_\lambda - n = \frac{3(\lambda+1)\sqrt{(2-\lambda)-(3-2\lambda)\sqrt{2\pi}}}{6\sqrt{\gamma(3-2\lambda)}} > 0 \]
\[ \frac{\partial p_{b,\lambda}}{\partial \lambda} = \frac{(17-11\lambda+2\lambda^2)t}{4(3-2\lambda)^2\sqrt{\gamma(t(2-\lambda))}} > 0 \]
\[ p_{b,\lambda} - p_b = -\sqrt{t} \frac{2\sqrt{\gamma(t(2-\lambda))(\lambda+1)-(4-\lambda)}}{2(\lambda+1)\sqrt{\gamma(2-\lambda)}} < 0 \]
\[ \frac{\partial q_{b,\lambda}}{\partial \lambda} = -\frac{ft(16-13\lambda+\lambda^2)}{4(\lambda+1)^2(2-\lambda)\sqrt{\gamma(t(2-\lambda))}} < 0 \]
\[ p_{g,\lambda} - p_g = \sqrt{t} \frac{\sqrt{\gamma(t(2-\lambda))}}{\sqrt{2\gamma(t(2-\lambda))}} > 0 \]
\[ \frac{\partial q_{g,\lambda}}{\partial \lambda} = \frac{\sqrt{t}}{2(2-\lambda)\sqrt{\gamma(t(2-\lambda))}} < 0 \]
\[ q_{b,\lambda} - q_b = \frac{\lambda(7-3\lambda)}{6(3-2\lambda)} < 0 \]
\[ \frac{\partial q_{b}}{\partial \lambda} = \frac{(2\lambda^2-6\lambda+7)}{2(3-2\lambda)^2} > 0 \]
\[ q_{g,\lambda} - q_g = \frac{\sqrt{t}}{2(2-\lambda)\sqrt{\gamma(t(2-\lambda))}} < 0 \]
\[ \frac{\partial q_{g}}{\partial \lambda} = -\frac{\sqrt{t}}{2(2-\lambda)\sqrt{\gamma(t(2-\lambda))}} < 0 \]
\[ Q_{g,\lambda} - Q_g = \frac{\lambda(7-3\lambda)}{6(3-2\lambda)} < 0 \]
\[ \frac{\partial Q_{g}}{\partial \lambda} = \frac{2\lambda^2-6\lambda+7}{2(2\lambda^3)} > 0 \]

Price Cap

\[ p_b^m - p_{b} = -\frac{\sqrt{t}f^{m}}{2\sqrt{\gamma(t)}} < 0 \]
\[ p_g^m - p_{g} = -\frac{\sqrt{t}f^{m}}{4\sqrt{\gamma(t)}} < 0 \]
\[ q_g^m - q_{g} = -\frac{\sqrt{t}f^{m}}{2\sqrt{\gamma(t)}} < 0 \]
\[ p_{b,\lambda}^m - p_{b,\lambda}^m = \frac{\sqrt{t}f(4-\lambda-m(2-3\lambda)-(2-m)2(\lambda+1)\sqrt{\gamma(t(2-\lambda))}}}{2(\lambda+1)\sqrt{(2-\lambda)}} > 0, \] if \( m < m^* = \frac{4(\lambda+1)\sqrt{\gamma(t(2-\lambda)-\sqrt{\gamma(t(2-\lambda))}}}{2(\lambda+1)\sqrt{\gamma(t(2-\lambda))}} > 0 \]
\[ p_{g,\lambda}^m - p_{g,\lambda}^m = \frac{\sqrt{t}f(2\sqrt{2}(2-m)\sqrt{2-\lambda})}{2\sqrt{2}(2-\lambda)} > 0 \]
\[ q_{g,\lambda}^m - q_{g,\lambda}^m = -\frac{\sqrt{t}f(2\sqrt{2}(2-m)\sqrt{2-\lambda})}{2\sqrt{2}(2-\lambda)} < 0 \]
\[ p_{b,\lambda}^m - p_{b,\lambda} = m(2-3\lambda)\sqrt{\gamma(t(2-\lambda))}{2(\lambda+1)(2-\lambda)} < 0 \]
\[ n^m - n_\lambda = -\frac{m(1-\lambda)(2-3\lambda)(\lambda+1)\sqrt{f^\tau(2-\lambda)}}{2\gamma(3-2\lambda)(m(2-3\lambda)(1-\lambda)+2\lambda(3-2\lambda))} < 0 \]
\[ q^m_{b,\lambda} - q_{b,\lambda} = \frac{m(1-\lambda)(2-3\lambda)(\lambda+1)}{2\gamma(3-2\lambda)(m(2-3\lambda)(1-\lambda)+2\lambda(3-2\lambda))} > 0 \]
\[ Q^m_{g,\lambda} - Q_{g,\lambda} = -\frac{m(1-\lambda)(2-3\lambda)(\lambda+1)}{2\gamma(3-2\lambda)(m(2-3\lambda)(1-\lambda)+2\lambda(3-2\lambda))} < 0 \]
\[ |(p^m_p - p_b)| = \left| \left( p^m_{b,\lambda} - p_{b,\lambda} \right) \right| = m\sqrt{\frac{4\gamma}{m(2-3\lambda)(1-\lambda)+2\lambda(3-2\lambda)}} > 0 \]
\[ |(p^p_g - p_g)| = \left| \left( p^p_{g,\lambda} - p_{g,\lambda} \right) \right| = \frac{\sqrt{4\gamma m}}{4\gamma} > 0 \]
\[ \frac{\partial (n^m - n_\lambda)}{\partial \lambda} = \frac{m\sqrt{\gamma(2-\lambda)(2(3-2\lambda)(24-5\lambda+8\lambda^2-92\lambda^3+4\lambda^4-6\lambda^5)}-m(17-11\lambda+2\lambda^2)(2-3\lambda)^2(1-\lambda)^2)}{4\gamma(2-\lambda)(2\lambda-3)^2(m(2-3\lambda)(1-\lambda)+2\lambda(3-2\lambda))^2} < 0 \]
\[ \frac{\partial (Q^m_{g,\lambda} - Q_{g,\lambda})}{\partial \lambda} = -\frac{m(2(3-2\lambda)(12-24\lambda+35\lambda^2-46\lambda^3+27\lambda^4-6\lambda^5)-m(7-6\lambda+2\lambda^2)(2-3\lambda)^2(1-\lambda)^2)}{2(3-2\lambda)^3(m(2-3\lambda)(1-\lambda)+2\lambda(3-2\lambda))^2} < 0 \]
\[ \frac{\partial (q^m_{b,\lambda} - q_{b,\lambda})}{\partial \lambda} = \frac{m(2(3-2\lambda)(12-24\lambda+35\lambda^2-46\lambda^3+27\lambda^4-6\lambda^5)-m(7-6\lambda+2\lambda^2)(2-3\lambda)^2(1-\lambda)^2)}{2(3-2\lambda)^3(m(2-3\lambda)(1-\lambda)+2\lambda(3-2\lambda))^2} < 0 \]

**Reference Price**

\[ n^r - n = -\frac{\sqrt{2\gamma f(\tau(1-\gamma)+\tau)}}{6\gamma(\tau(1-\gamma)+\tau)} < 0 \]
\[ p^p_b - p_b = -\frac{\sqrt{2\gamma f(\tau(1-\gamma)+\tau)}}{\sqrt{\gamma(\tau(1-\gamma)+\tau)}} < 0 \]
\[ p^p_g - p_g = -\frac{\sqrt{2\gamma f(\tau(1-\gamma)+\tau)}}{\sqrt{2\gamma(\tau(1-\gamma)+\tau)}} < 0 \]
\[ q^p_b - q_b = \frac{\sqrt{4\gamma m}}{4\gamma} > 0 \]
\[ n^m - n^r = \frac{3(1+\lambda)\sqrt{\gamma(\tau(1-\gamma)+\tau)}}{6\gamma(\tau(1-\gamma)+\tau)} \frac{\sqrt{\gamma(2-\lambda)+2\tau(1-\gamma)(1-\lambda)}-\sqrt{\gamma(3\tau(1-\gamma)(1-\lambda)+\gamma(3-2\lambda))}}{2(\lambda+1)(1-\gamma)(1-\lambda)+2\tau(1-\gamma)(1-\lambda)} > 0 \]
\[ p^b_{b,\lambda} - p_b = -\frac{\sqrt{\gamma(2\lambda-2\tau(\tau(1-\gamma)+\tau)+(3-2\lambda))}}{2\tau(1-\gamma)(1-\lambda)+2\tau(1-\gamma)(1-\lambda)} > 0 \]
\[ q^b_{b,\lambda} - q_b = \frac{\sqrt{2\gamma(\tau(1-\gamma)+\tau)}}{\sqrt{2\gamma(\tau(1-\gamma)+\tau)}} > 0 \]
\[ Q^r_{g,\lambda} - Q^r_{g,\lambda} = \frac{\sqrt{2\gamma(\tau(1-\gamma)+\tau)}}{\sqrt{2\gamma(\tau(1-\gamma)+\tau)}} > 0 \]
\[ n^r - n = -\frac{\sqrt{4\gamma m}}{4\gamma} > 0 \]
\[ p^r_b - p_b = -\frac{\sqrt{4\gamma m}}{4\gamma} > 0 \]
\[ q^r_b - q_b = \frac{\sqrt{4\gamma m}}{4\gamma} > 0 \]
\[ Q^r_g - Q^r_g = \frac{\sqrt{4\gamma m}}{4\gamma} > 0 \]
\[ n^r - n = -\frac{\sqrt{4\gamma m}}{4\gamma} > 0 \]
\[ p^r_b - p_b = -\frac{\sqrt{4\gamma m}}{4\gamma} > 0 \]
\[ q^r_b - q_b = \frac{\sqrt{4\gamma m}}{4\gamma} > 0 \]
\( q_{g,\lambda} - q_{g,\lambda} = \sqrt{\frac{1}{f}} \left( \sqrt{\gamma(2-\lambda)+2r(1-\gamma)(1-\lambda)} - \sqrt{\gamma(2-\lambda)} \right) > 0 \)

\( Q_{g,\lambda} - Q_{g,\lambda} = -\frac{\lambda(1+\lambda)(1-\gamma)(1-\lambda)}{2(3-2\lambda)m(3-2\lambda)(1-\lambda)(1+\lambda)(1-\gamma)(1-\lambda)} < 0 \)

\( \{n_{\lambda} - n_{\lambda}\} - \{n_{\lambda} - n_{\lambda}\} = \frac{f_3(3\sqrt{f}(r(1-\gamma)+(1+\lambda))\left( \sqrt{\gamma(2-\lambda)+2r(1-\gamma)(1-\lambda)} - \sqrt{\gamma(2-\lambda)(3-2\lambda)(1-\lambda)(1-\gamma)(1-\lambda)} \right) \right) \}

\( = \frac{f_3(3\sqrt{f}(r(1-\gamma)+(1+\lambda))\left( \sqrt{\gamma(2-\lambda)+2r(1-\gamma)(1-\lambda)} - \sqrt{\gamma(2-\lambda)(3-2\lambda)(1-\lambda)(1-\gamma)(1-\lambda)} \right) \right) \}

\( \frac{\sqrt{\gamma(r(1-\gamma)+\gamma)(2-\lambda)(\gamma(4-\lambda)+2r(1-\gamma)(2-\lambda))}}{2}\sqrt{\gamma(r(1-\gamma)+\gamma)(2-\lambda)(\gamma(4-\lambda)+2r(1-\gamma)(2-\lambda))}

\( + \frac{\sqrt{\gamma(r(1-\gamma)+\gamma)(2-\lambda)(\gamma(4-\lambda)+2r(1-\gamma)(2-\lambda))}}{2}\sqrt{\gamma(r(1-\gamma)+\gamma)(2-\lambda)(\gamma(4-\lambda)+2r(1-\gamma)(2-\lambda))} < 0 \)

\( \left| \left( p_{g,\lambda} - p_{g,\lambda} \right) \right| - \left| \left( p_{g,\lambda} - p_{g,\lambda} \right) \right| = -\frac{\sqrt{\gamma(r(1-\gamma)+\gamma)(2-\lambda)(\gamma(4-\lambda)+2r(1-\gamma)(2-\lambda))}}{2}\sqrt{\gamma(r(1-\gamma)+\gamma)(2-\lambda)(\gamma(4-\lambda)+2r(1-\gamma)(2-\lambda))}

\( + \frac{\sqrt{\gamma(r(1-\gamma)+\gamma)(2-\lambda)(\gamma(4-\lambda)+2r(1-\gamma)(2-\lambda))}}{2}\sqrt{\gamma(r(1-\gamma)+\gamma)(2-\lambda)(\gamma(4-\lambda)+2r(1-\gamma)(2-\lambda))} < 0 \)

\( \left| \left( q_{g,\lambda} - q_{g,\lambda} \right) \right| - \left| \left( q_{g,\lambda} - q_{g,\lambda} \right) \right| = -\frac{\sqrt{\gamma(r(1-\gamma)+\gamma)(2-\lambda)(\gamma(4-\lambda)+2r(1-\gamma)(2-\lambda))}}{2}\sqrt{\gamma(r(1-\gamma)+\gamma)(2-\lambda)(\gamma(4-\lambda)+2r(1-\gamma)(2-\lambda))}

\( + \frac{\sqrt{\gamma(r(1-\gamma)+\gamma)(2-\lambda)(\gamma(4-\lambda)+2r(1-\gamma)(2-\lambda))}}{2}\sqrt{\gamma(r(1-\gamma)+\gamma)(2-\lambda)(\gamma(4-\lambda)+2r(1-\gamma)(2-\lambda))} < 0 \)

Welfare

\( C^n - C^t = -\sqrt{2tf} \frac{\sqrt{\gamma(r(1-\gamma)+\gamma)(2-\lambda)(\gamma(4-\lambda)+2r(1-\gamma)(2-\lambda))}}{12\sqrt{\gamma(r(1-\gamma)+\gamma)}} < 0 \)

\( C^\lambda_n - C_\lambda = -\frac{\sqrt{\gamma(r(2-\lambda)(2-3\lambda)(1-\lambda))/(12(12\gamma+4\gamma\lambda^2+20\gamma^2(2-\lambda)^2(\gamma^2+8)+17\lambda^2\gamma^2)+8) - 2m(2-\lambda)(3-2\lambda)(1-\lambda)(1+\lambda)+(1+\lambda)^2(1-\lambda)+2(1-\lambda)^2(1-\lambda)+2(1-\lambda)^2(1-\lambda))} < 0 \)

\( C^\lambda_m - C_\lambda = -\frac{\sqrt{\gamma(r(2-\lambda)(2-3\lambda)(1-\lambda))/(12(12\gamma+4\gamma\lambda^2+20\gamma^2(2-\lambda)^2(\gamma^2+8)+17\lambda^2\gamma^2)+8) - 2m(2-\lambda)(3-2\lambda)(1-\lambda)(1+\lambda)+(1+\lambda)^2(1-\lambda)+2(1-\lambda)^2(1-\lambda)+2(1-\lambda)^2(1-\lambda))} < 0 \)

\( C^n - C^t = -\frac{\sqrt{\gamma(r(2-\lambda)(2-3\lambda)(1-\lambda))/(12(12\gamma+4\gamma\lambda^2+20\gamma^2(2-\lambda)^2(\gamma^2+8)+17\lambda^2\gamma^2)+8) - 2m(2-\lambda)(3-2\lambda)(1-\lambda)(1+\lambda)+(1+\lambda)^2(1-\lambda)+2(1-\lambda)^2(1-\lambda)+2(1-\lambda)^2(1-\lambda)} < 0 \)