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# Non-horizontal mergers with investments into compatibility

## Abstract

We set up a model to analyze the effects of mergers between sellers of complementary components where firms invest in compatibility and can engage in bundling. We consider the impact of merger on prices, investment and consumer surplus. We also analyse when the merged firm may have an incentive and ability to foreclose rivals.

JEL-Codes: L130, L410.

Keywords: mergers, complementary goods, welfare effects, foreclosure, compatibility.

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# 1 Introduction

In several recent mergers, the European Commission (EC) raised concerns related to mixed bundling and degradation of interoperability between the merged firm's products and complementary products of its non-integrated rivals.

An example is the proposed (and later abandoned) merger between Qualcomm and NXP. Qualcomm manufactures and sells LTE baseband chipsets, while NXP manufactures and sells NFC/SE chips. To mobile device manufacturers, the two chipsets are complementary as they must be combined in smartphones to provide the functionalities that final customers demand.

In its assessment, the EC found that the merged firm would have an incentive to offer a discount on the bundle of LTE and NFC/SE chipsets while increasing the prices for standalone sales. The EC was concerned that this could result in an anti-competitive foreclosure of the merged firm's rivals. The EC was also concerned that the merger could lead to a decreased interoperability of NFC/SE chipsets with third party baseband chipsets, limiting their ability to effectively compete and ultimately harming consumers. The EC assessed similar concerns in GE-Avio, Airbus-Safran, ASL-Arianespace, Broadcom-Brocade and Essilor-Luxotica.

To analyze whether – and when – the EC's concerns with interoperability are justified, we set up a model where the effects of the merger simultaneously materialize via mixed bundling and the effort that firms put into interoperability. We use the model to analyze the impact of a merger on prices, investment into compatibility and the incentive and ability of the merged firm to foreclose its non-integrated rivals.

A related paper to ours is Choi (2008). Choi, using linear-quadratic demand specification, studies the incentive of the merged firm to engage in mixed bundling and derives welfare implications of mergers. He also studies the implication of mergers for innovation incentives. He does not, however, address investment in compatibility and the scope for strategic foreclosure.

As Choi's (2008), our model features strictly complementary components that are combined into composite goods (systems) by customers. In our setting, on top of that, each firm may invest effort in compatibility (or interoperability) with the complementary component before competing in prices. We also use a different from Choi's specification of the demand system as a leading example.

Before turning to a full equilibrium analysis for a particular demand and cost specification, we analyse a general setting with regular demand that generates quasiconcave profits. This allows us to identify four distinct effects of a merger, each caused by a particular modeling feature.

Firstly, the merger always has a Cournot effect that works in the direction of providing a bundling discount. Second, when the composite goods are substitutes, there is also a horizontal effect that removes implicit (or indirect) competition between components of merging firms and therefore works in the direction of the increase of standalone prices. Third, when there are demand asymmetries such that the merging firms would like to price-differentiate, there is also a price-discrimination effect, the direction of which is determined by the shape of the demand asymmetry.

Fourth, when investment into compatibility is possible, there is an investment effect that internalises a positive externality of investing on the demand for own product and a negative externality of investing on the demand for mix-and-match product. The effect is, correspondingly, to increase investment into compatibility of bundled product and to decrease investment into compatibility of mix-and-match products.

In our linear example, a merger typically increases consumer surplus, and even more so when we allow for investments into compatibility. This is because the merged firms are now internalizing two sources of pre-merger inefficiencies. The first one is the well-known Cournot pricing effect. The second one is the positive spillover from the effort that one firm puts into compatibility with a complementary component. The spillover results in a free-riding problem; the merger solves this problem for the merging parties who invest more into compatibility between own components.

We also find that investment into compatibility may harm rivals' profits more than mixed bundling alone. This increases the scope for foreclosure. Moreover, while, without investment, firms never strategically foreclose their rivals, they may do so when facing the option to invest into interoperability.

We conclude that the antitrust authority should not simply stack the effects of mixed bundling on top of the effects on interoperability. Both these effects are often pro-competitive. At the same time, interoperability may enhance the risk of foreclosure in specific circumstances.

Our contribution is twofold: we add both to academic treatment of the consequences that mergers between producers of compliments and to the practitioners' debate on the likely effects of such mergers on competition. Adachi and Ebina (2014) study the consequences of a merger between monopolists producing unidirectional complements. Alvisi et al (2011) analyse the consequences of a merger between strict complements in a setting with exogenous quality differentiation. Barros et al (2018) find that welfare-decreasing mergers are possible in a setting with a monopolist and two vertically-differentiated producers pre-merger. Flores-Fillol and Moner-Colonques (2011) study the mergers in Choi (2008) setting with additional feature that standalone components bring utility for some consumers. Mialon (2014) uses Hotelling model to find that firms prefer merger to strategic alliance only if they aim at foreclosure.

Another strand of related literature does not address mergers, but various phenomena in complementary markets. For example, Avenali et al (2013) investigate how bundling affects investment in product quality. Mantovani (2013) studies incentives of a producer of two complementary goods to bundle in presence of competition.

Yet another large literature that is close to our paper is that on vertical integration and investment incentives. An exemplary contribution here is by Allain et al (2016) showing that vertical integration may create hold-up problems both ex ante (an integrated supplier may pre-commit itself to being greedy and thus discourage investment of downstream rivals) and ex post (by degradation of quality provided to downstream rivals - a kind of vertical foreclosure). Salinger

(1991) analyses a situation in which a two-product monopolist mergers with one of its suppliers, showing that, despite Cournot effect, one or even two prices can be higher post-merger.

Song et al (2017) empirically identify two of the effects that we discuss in our paper in the context of pharmaceutical cocktails. In particular, they assess horizontal (competition) and Cournot effect. Ershov et al (2018) estimate a discrete choice model that allows for demand complementarity in the context of potato chips and carbonated soda pop.

The rest of the paper is structured as follows. We generalise Choi's (2008) results for arbitrary regular demand systems and characterize the general price effects in Section 2. We introduce investment into compatibility and discuss associated general effects in Section 3. In Section 4, we summarize the numerical results of modeling a particular linear demand system. In Section 5, we discuss in more detail how the merger effects depend on the substitutability parameter. In Section 6, we discuss foreclosure possibilities in our linear demand model, and in Section 7, we analyse the role of asymmetries for our numerical results.

## 2 Simple setting

Our setting features differentiated substitutable composite goods (systems) made of two perfectly complementary components. There are two differentiated brands of each of the components $A$ ($A_1$, $A_2$) and $B$ ($B_1$, $B_2$). Consequently, there are potentially 4 competing systems – $A_1B_1$, $A_1B_2$, $A_2B_1$, $A_2B_2$ – each combining two components of respective brands. Before a merger, the system components are sold by single-brand firms. A merger brings components $A_1$ and $B_1$ under single ownership.

Let the price of component $A_i$ be $p_i$ and the price of component $B_j$ be $q_j$, where $i, j \in \{1, 2\}$. Then, the system $A_iB_j$ is available at the total system price of $s_{ij} \leq p_i + q_j$. Following a merger a single firm offers both components $A_i$ and $B_j$ and may choose to offer the product $A_iB_j$ with a bundled discount, i.e. at $s_{ij} < p_i + q_j$. Let $d_{ij}$ denote demand for the system $A_iB_j$.

The four systems are substitutes for one another: $d_{ij}$ is decreasing in its own price and increasing in the prices of the three substitute systems. For instance, $d_{11}$ is decreasing in $s_{11}$, and increasing in $s_{12}, s_{21}$ and $s_{22}$. The demand for a system is also decreasing in the quality of other systems.

The demand functions for the components can be obtained from the demand functions for the systems. For instance, component $A_i$ is sold as a part of systems $A_iB_1$, $A_iB_2$. Thus, the demand for component $A_i$ is given by

$$D^{A_i} = d_{i1} + d_{i2}.$$

Similarly, the demand for component $B_j$ is given by

$$D^{B_j} = d_{1j} + d_{2j}.$$

We model market interaction as a two-stage game. In each stage, the choices are simultaneous, i.e. no firm has power to commit. In the first stage, firms choose investment in compatibility; in the second stage, they compete in prices after having observed the quality of the systems on offer.[1]

## 2.1 Demand

Consider a generic downward-sloping demand for substitute composite goods $\mathbf{d}(\mathbf{s})$, each component of which is a function $d_{ij} : \mathbb{R}_+^4 \to \mathbb{R}_+$ with $\frac{\partial d_{ij}}{\partial s_{ij}} < 0$, $\frac{\partial d_{ij}}{\partial s_{-ij}} > 0$ and $\sum_{-ij} \frac{\partial d_{ij}}{\partial s_{-ij}} < \left| \frac{\partial d_{ij}}{\partial s_{ij}} \right|$ at the pre-merger equilibrium. We assume that profits generated by this demand function are a quasiconcave function of each price. We further assume that the demand system is regular in the sense that the cross-price effects on marginal revenue are sufficiently small.

Moreover, the family of demand functions is characterized by a quality parameter vector $\mathbf{u}$ such that $\frac{\partial d_{ij}}{\partial u_{ij}} > 0$, $\frac{\partial d_{ij}}{\partial u_{-ij}} \leq 0$. We can then write the demand for each composite good as $d_{ij}\left(s_{ij}, s_{-ij}; u_{ij}, u_{-ij}\right)$.

## 2.2 Pre-merger and post-merger equilibrium conditions

Pre-merger, we consider a setting with four firms, each producing a single component (which can be used in two different products). In the second stage (pricing game), the maximisation problems of the firms are

$$\begin{aligned} \max_{p_i}(p_i - e_{Ai})\left(d_{i1} + d_{i2}\right), i &\in \{1,2\}, \\ \max_{q_j}(q_j - e_{Bj})\left(d_{1j} + d_{2j}\right), j &\in \{1,2\}. \end{aligned}$$

where $e_{Ai}$ and $e_{Bj}$ denote the unit cost of components $A_i$ and $B_j$, respectively. We set these to zero for now.

The FOCs look like

$$d_{i1} + d_{i2} + p_i \left( \frac{\partial d_{i1}}{\partial s_{i1}} + \frac{\partial d_{i1}}{\partial s_{i2}} + \frac{\partial d_{i2}}{\partial s_{i2}} + \frac{\partial d_{i2}}{\partial s_{i1}} \right) = 0 \qquad (1)$$

for the producer of the component $A_i$, and

$$d_{1j} + d_{2j} + q_j \left( \frac{\partial d_{1j}}{\partial s_{1j}} + \frac{\partial d_{1j}}{\partial s_{2j}} + \frac{\partial d_{2j}}{\partial s_{2j}} + \frac{\partial d_{2j}}{\partial s_{1j}} \right) = 0 \qquad (2)$$

for the producer of the component $B_j$.

The equations show the familiar equality of the marginal benefit from increasing a component price (that is the sum of demands - first two terms) and the marginal cost in terms of lost demand net of the demand gain from the increase of price of the substitute product (that happens automatically because each component is present in two substitute composite products).

[1] There is no uncertainty; the outcomes of the first stage can be observed by all market participants, so firms condition their second-stage actions (prices) on the first-stage outcomes (systems quality).

Before switching attention to post-merger, we first consider a situation in which merging firms can set different prices for the same component when it participates in different composite products. We will use the results in this scenario as a benchmark in our analysis of the scenario without such price discrimination.

The pre-merger FOC in the price discrimination scenario for firms $A_1$ and $B_1$ (the merging firms) are

$$d_{11} + p_{11}\frac{\partial d_{11}}{\partial s_{11}} + p_{12}\frac{\partial d_{12}}{\partial s_{11}} = 0, \tag{3a}$$

$$d_{12} + p_{11}\frac{\partial d_{11}}{\partial s_{12}} + p_{12}\frac{\partial d_{12}}{\partial s_{12}} = 0, \tag{3b}$$

$$d_{11} + q_{11}\frac{\partial d_{11}}{\partial s_{11}} + q_{21}\frac{\partial d_{21}}{\partial s_{11}} = 0, \tag{3c}$$

$$d_{21} + q_{11}\frac{\partial d_{11}}{\partial s_{21}} + q_{21}\frac{\partial d_{21}}{\partial s_{21}} = 0, \tag{3d}$$

and it is clear that, with price discrimination, prices of the same component may differ, reflecting possible asymmetries in demand.

After merger, a single firm produces and sells two components that may be combined into a system without involving other firms; there are also two standalone firms. Consequently, the integrated firm may set prices of all-own system $A_1B_1$ to $s_{11}$ below or equal to the sum of the prices of the corresponding components. The price for other systems is $s_{ij} = p_i + q_j$.

The maximization problem of the integrated firm is:

$$\max_{s_{11}, p_1, q_1} s_{11}d_{11} + p_1 d_{12} + q_1 d_{21}.$$

The maximization problems of the standalone firms are the same as pre-merger.

In terms of discriminating prices, the post-merger FOCs are

$$d_{11} + s_{11}\frac{\partial d_{11}}{\partial s_{11}} + p_{12}\frac{\partial d_{12}}{\partial s_{11}} + q_{21}\frac{\partial d_{21}}{\partial s_{11}} = 0, \tag{4a}$$

$$s_{11}\frac{\partial d_{11}}{\partial s_{12}} + d_{12} + p_{12}\frac{\partial d_{12}}{\partial s_{12}} + q_{21}\frac{\partial d_{21}}{\partial s_{12}} = 0, \tag{4b}$$

$$s_{11}\frac{\partial d_{11}}{\partial s_{21}} + d_{21} + p_{12}\frac{\partial d_{12}}{\partial s_{21}} + q_{21}\frac{\partial d_{21}}{\partial s_{21}} = 0. \tag{4c}$$

## 2.3 Comparison

By summing up the conditions for $p_{11}$ and $q_{11}$ in the discrimination case, (3a) and (3c), we have

$$2d_{11} + p_{11}\frac{\partial d_{11}}{\partial s_{11}} + p_{12}\frac{\partial d_{12}}{\partial s_{11}} + q_{11}\frac{\partial d_{11}}{\partial s_{11}} + q_{21}\frac{\partial d_{21}}{\partial s_{11}}$$

Correspondingly, the difference, at pre-merger prices, of the post-merger condition (4a) with the pre-merger discrimination case is $d_{11}$. The missing post-merger term $d_{11}$ is exactly the Cournot (or double-marginalisation) effect. At pre-merger prices, this makes the post-merger profit derivative negative and to bring it to the optimum, the bundle price should decrease by quasiconcavity of profit post-merger (quasiconcavity ensures that the first derivative is positive to the left of the optimum and negative to the right). Thus, if price discrimination is allowed before merger, the price of bundled good always goes down post-merger in our setting. [2]

The difference between the conditions for $p_{12}$, (4b) and (3b), at pre-merger prices, is

$$-q_{11}\frac{\partial d_{11}}{\partial s_{12}} - q_{21}\frac{\partial d_{21}}{\partial s_{12}}, \tag{5}$$

which is negative, meaning that the standalone prices rise post-merger relative to differentiated prices pre-merger.[3] Intuitively, this is a classical horizontal effect that reflects internalisation of the effect of pricing decision for A1 on the revenue from complementary component B1.

**Proposition 1.** Suppose, pre-merger price discrimination is allowed for the merging firms. A merger then leads to a decrease in price of the composite good assembled solely from the components of the merging firms, $s_{11}^1 < p_{11}^0 + q_{11}^0$. The component prices of the merging firms, however, rise, $p_1^1 > p_{12}^0; q_1^1 > q_{12}^0$.

**Proof** Follows from the discussion above. The result $q_1^1 > q_{12}^0$ can be established analogously to the result $p_1^1 > p_{12}^0$ by comparing conditions (4c) and (3d).

Here and in the rest of the text, we denote equilibrium values pre-merger with a zero superscript and equilibrium values post-merger with a unity superscript.

Note that in a perfectly symmetric setting, $p_{11} = p_{12} = p_1$ and $q_{11} = q_{12} = q_1$, so there is no reason to price-discriminate pre-merger. This leads us to the following corollary, generalising results in Choi (2008) for non-linear demand systems satisfying our regularity assumptions (quasiconcavity and not too high cross-price effects for both demand and marginal revenue):

**Corollary** For perfectly symmetric demand systems, a merger leads to a decrease in price of the composite good assembled solely from the components of the merging firms, $s_{11}^1 < p_1^0 + q_1^0$. The component prices of the merging firms, however, rise, $p_1^1 > p_1^0; q_1^1 > q_1^0$.

[2] We can make this statement because mix-and-match prices rise and our assumption on demand regularity ensures that their effect on the marginal revenue from the bundled product cannot override or even cancel the Cournot effect.

[3] Again, we can make this statement in terms of the price rise rather than in terms of an effect that rises price because bundled price goes down and our assumption on demand regularity ensures that its effect on the marginal revenue from the standalone component cannot override or even cancel the horizontal effect.

Intuitively, the results of Proposition 1 will be robust to generalisation to asymmetric demand systems unless the following condition on demand system is satisfied: The demand asymmetries are such that, pre-merger, allowing price discrimination for merging firms would result in substantial price increase of the component that is involved in bundling and price decrease of the same component involved in the mix-and-match solution. This is formalized in the following proposition:

**Proposition 1a.** A merger leads to a decrease in price of the composite good assembled solely from the components of the merging firms, $s_{11}^1 < p_1^0 + q_1^0$, under the following condition on pre-merger outcome:

$$d_{11} + d_{12} + p_1 \left( \frac{\partial d_{11}}{\partial s_{12}} + \frac{\partial d_{12}}{\partial s_{12}} \right) + d_{21} + q_1 \left( \frac{\partial d_{11}}{\partial s_{21}} + \frac{\partial d_{21}}{\partial s_{21}} \right) > 0; \qquad (6)$$

it leads to the rise of the component prices of the merging firms, $p_1^1 > p_1^0; q_1^1 > q_1^0$, under the pre-merger conditions

$$d_{11} + p_1 \left( \frac{\partial d_{11}}{\partial s_{11}} + \frac{\partial d_{12}}{\partial s_{11}} \right) - q_1 \left( \frac{\partial d_{11}}{\partial s_{12}} + \frac{\partial d_{21}}{\partial s_{12}} \right) < 0, \qquad (7)$$

$$d_{11} + q_1 \left( \frac{\partial d_{11}}{\partial s_{11}} + \frac{\partial d_{21}}{\partial s_{11}} \right) - p_1 \left( \frac{\partial d_{11}}{\partial s_{21}} + \frac{\partial d_{12}}{\partial s_{21}} \right) < 0. \qquad (8)$$

**Proof** To obtain the first result, we sum up pre-merger conditions (1) and (2) for $i = 1$ an $j = 1$. We then compare the resulting expression with post-merger condition (4a) at pre-merger prices. By quasiconcavity of profits in $s_{11}$, keeping other prices fixed, $s_{11}$ must decline from its pre-merger level $p_1^0 + q_1^0$ whenever (6) is satisfied. For obtaining the second result (for $p_1$), we compare pre-merger condition (1) with post-merger condition (4b) at pre-merger prices. By quasiconcavity of profits in $p_1$, keeping other prices fixed, $p_1$ must increase from its pre-merger level $p_1^0$ whenever (7) is satisfied. Two results together with the assumption that the cross-price effects in marginal revenue The proof for $q_1$ is completely analogous. Finally, we use the regularity assumption to ensure that simultaneous change in prices does not result in cross-price effects overriding the initial effects of merger described here. [4]

The terms in each of the conditions derived in Proposition 1a identify various effects of the merger. In condition (6), $d_{11}$ represents Cournot effect while $d_{12} + p_1 \left( \frac{\partial d_{11}}{\partial s_{12}} + \frac{\partial d_{12}}{\partial s_{12}} \right)$ and $d_{21} + q_1 \left( \frac{\partial d_{11}}{\partial s_{21}} + \frac{\partial d_{21}}{\partial s_{21}} \right)$ each represents price-discrimination effect for each of the respective two system components; in

[4] In particular, if the marginal revenue described by the lhs of (4a) is decreasing in $p_1$ and $q_1$, the initial effect is amplified; if it is increasing in these prices, the initial effect is curbed - the regularity assumption is needed to assure that the initial effect is not cancelled out. Analogously, the effect of changes in $s_{11}$ and $q_1$ on marginal revenue described by the lhs of (4b) may intensify or hinder the initial effect, and the regularity assumption ensures that the hindrance will not be too large.

condition (7), $-q_1\left(\frac{\partial d_{11}}{\partial s_{12}}+\frac{\partial d_{21}}{\partial s_{12}}\right)$ represents horizontal effect (loss of indirect competition due to the merger), while $d_{11}+p_1\left(\frac{\partial d_{11}}{\partial s_{11}}+\frac{\partial d_{12}}{\partial s_{11}}\right)$ represents price-discrimination effect.

While we have already discussed Cournot and competition effects when comparing price-discrimination benchmark with post-merger outcome, the price discrimination effect appears when comparing no-discrimination pre-merger with post-merger and deserves some attention as well. Pre-merger, it is impossible to set different prices for, say, component A1 sold for product A1B1 and component A1 sold for product A1B2. Post-merger, such price discrimination becomes possible as bundle price is set separately from the component price in mix-and-match solution. As can be seen from (3b), the marginal revenue from increasing standalone price $p_{12}$ over its bundled counterpart $p_{11}$ is $d_{12}+p_1\left(\frac{\partial d_{11}}{\partial s_{12}}+\frac{\partial d_{12}}{\partial s_{12}}\right)$, where the first term represent a direct gain in terms of higher price for product A1B2, whereas the second term is the loss in terms of lower demand for product A1B2 net of the increase of demand for product A1B1. At price discriminating equilibrium pre-merger, this effect is zero. However, without price discrimination, the marginal revenue is generally nonzero.

If the marginal revenue is positive, this provides an incentive to charge higher price $p_{12}$ relative to price $p_{11}$. For fixed $p_{12}$, this is equivalent to the incentive of decreasing $s_{11}$, thus reinforcing Cournot effect. If the marginal revenue is negative, it provides an incentive to increase $s_{11}$, thus mitigating Cournot effect. The marginal revenue with respect to $p_{12}$ is positive whenever the uniform price $p_1$ is too high relative to the price-discrimination outcome $p_{12}$; in other words, whenever $p_{11}>p_{12}$ in the price-discrimination equilibrium. Conversely, the marginal revenue with respect to $p_{12}$ is negative whenever the uniform price $p_1$ is too low relative to the price-discrimination outcome $p_{12}$; in other words, whenever $p_{11}<p_{12}$ in the price-discrimination equilibrium.

The term $d_{21}+q_1\left(\frac{\partial d_{11}}{\partial s_{21}}+\frac{\partial d_{21}}{\partial s_{21}}\right)$ is the marginal revenue with respect to standalone price $q_{21}$, as can also be seen from (3d). The intuition and direction of this price-discrimination effect is analogous to the one just discussed. At the same time, $d_{11}+p_1\left(\frac{\partial d_{11}}{\partial s_{11}}+\frac{\partial d_{12}}{\partial s_{11}}\right)$ is the marginal revenue with respect to standalone price $p_{11}$, as we see from (3a). By (1), it has the sign opposite to that of the marginal revenue with respect to $p_{12}$. Analogously, by (10), the marginal revenue with respect to standalone price $q_{11}$ has the sign opposite to that of the marginal revenue with respect to $q_{21}$.

To sum up, in a simple setting with strict complementarity, there are three effects of a merger:

- Cournot effect - always puts a downward pressure on the price of the bundle provided by the merging firms;
- Horizontal (competition) effect - always puts an upward pressure on the price of the standalone components provided by the merging firms;
- Price discrimination effect - may put upward or downward pressure on

the prices of the components provided by the merging firms, depending on the direction of the demand asymmetry between bundled and mix-and-match solutions. In particular, whenever $p_{11}^0 < p_{12}^0$ or $q_{11}^0 < q_{21}^0$, price discrimination works in the direction opposite to Cournot and competition effects.

The reaction of outsiders depends on strategic complementarity/substitutability of prices. Along the best response, the slope of, e.g., price for A2 with respect to prices of the merged firm can be found using a standard comparative statics exercise

$$\begin{aligned}
\frac{\partial d_{21}}{\partial s_{11}} + \frac{\partial d_{22}}{\partial s_{11}} + p_2\left(\frac{\partial^2 d_{21}}{\partial s_{21}\partial s_{11}} + \frac{\partial^2 d_{22}}{\partial s_{21}\partial s_{11}} + \frac{\partial^2 d_{21}}{\partial s_{22}\partial s_{11}} + \frac{\partial^2 d_{22}}{\partial s_{22}\partial s_{11}}\right) &= -\pi_{p_2 p_2}\frac{dp_2}{ds_{11}} \\
\frac{\partial d_{21}}{\partial s_{12}} + \frac{\partial d_{22}}{\partial s_{12}} + p_2\left(\frac{\partial^2 d_{21}}{\partial s_{21}\partial s_{12}} + \frac{\partial^2 d_{22}}{\partial s_{21}\partial s_{12}} + \frac{\partial^2 d_{21}}{\partial s_{22}\partial s_{12}} + \frac{\partial^2 d_{22}}{\partial s_{22}\partial s_{12}}\right) &= -\pi_{p_2 p_2}\frac{dp_2}{dp_1} \\
\frac{\partial d_{21}}{\partial s_{21}} + \frac{\partial d_{22}}{\partial s_{21}} + p_2\left(\frac{\partial^2 d_{21}}{\partial s_{21}^2} + \frac{\partial^2 d_{22}}{\partial s_{21}^2} + \frac{\partial^2 d_{21}}{\partial s_{22} s_{21}} + \frac{\partial^2 d_{22}}{\partial s_{22} s_{21}}\right) &= -\pi_{p_2 p_2}\frac{dp_2}{dq_1}
\end{aligned}$$

The sign is in general dependent on the mixed derivatives of the demand system. In particular, in linear case that turns into

$$\begin{aligned}
\frac{\partial d_{21}}{\partial s_{11}} + \frac{\partial d_{22}}{\partial s_{11}} &> 0 \\
\frac{\partial d_{21}}{\partial s_{12}} + \frac{\partial d_{22}}{\partial s_{12}} &> 0 \\
\frac{\partial d_{21}}{\partial s_{21}} + \frac{\partial d_{22}}{\partial s_{21}} &< \; >= 0
\end{aligned}$$

For sufficiently symmetric systems, $\frac{\partial d_{21}}{\partial s_{21}} + \frac{\partial d_{22}}{\partial s_{21}} < 0$ and therefore the effect of the merger is to decrease the price of outsiders.

# 3 Compatibility investment

We now study the effects of a merger on compatibility investment. Each firm may invest separately into compatibility of its component with each of the two complementary components. The investment increases the quality of the corresponding system. The compatibility quality $\delta_{ij}$ of the product $A_i B_j$ depends directly on the two investments: $\eta_{ij}$, the investment of the producer of component $A_i$ into compatibility with component $B_j$; and $\xi_{ji}$, the investment of the producer of component $B_j$ into compatibility with component $A_i$. It may also depend indirectly on the investment of all other firms, $\{\eta_{-ij}\}$ and$\{\xi_{-ij}\}$. The compatibility quality profile is denoted by vector $\Delta := \{\delta_{ij}\}$. Since we only model compatibility aspects of quality we can assume that $\mathbf{u} \equiv \Delta$ (i.e. normalise the mapping from compatibility quality to product quality to unity).

We assume that $\frac{\partial \delta_{ij}}{\partial \eta_{ij}} > 0$ and $\frac{\partial \delta_{ij}}{\partial \xi_{ji}} > 0$; the effect of investment on compatibility of other products may be either positive (positive externality), negative (negative externality) or zero (neutrality).

The cost of investment is characterised by function $k : \mathbb{R}_+^2 \to \mathbb{R}_+$ that maps the investments in the compatibility of own component with each of the two other components into a monetary expense. We do not model possible asymmetries in the investment cost function. We allow for the merger to lead to efficiencies reflected in the reduction of the investment cost relative to the sum of investment cost functions. Naturally, investment cost function is increasing in each of the arguments, $\frac{\partial k(\eta_{ij}, \eta_{-i,j})}{\partial \eta_{ij}} > 0$. We also require $k$ to be convex.

## 3.1 Pre-merger equilibrium

For a given product quality profile $\Delta$, we denote the equilibrium price profile with $P(\Delta) := \left\{p_i^*, q_j^*\right\}, i = \{1,2\}, j = \{1,2\}$. The maximized profits as functions of the product quality profile are

$$\begin{aligned} \pi_{A_i}(\Delta) &= p_i^*\left(d_{i1}(P) + d_{i2}(P)\right), i \in \{1,2\}; \\ \pi_{B_j}(\Delta) &= q_j^*\left(d_{1j}(P) + d_{2j}(P)\right), j \in \{1,2\}. \end{aligned}$$

where $P$ is a function of $\Delta$.

In the first stage, firms maximize

$$\begin{aligned} &\pi_{A_i}(\Delta) - k(\eta_{i1}, \eta_{i2}), \\ &\pi_{B_j}(\Delta) - k(\xi_{j1}, \xi_{j2}). \end{aligned}$$

by choosing $\eta_{ij}$ and $\xi_{ij}$ appropriately for the components they offer. The FOCs are then of the form

$$p_i^*\left(\frac{\partial d_{i1}(P)}{\partial \eta_{ij}} + \frac{\partial d_{i2}(P)}{\partial \eta_{ij}}\right) = \frac{\partial k(\eta_{i1}, \eta_{i2})}{\partial \eta_{ij}}, i, j \in \{1,2\}; \tag{9a}$$

$$q_j^*\left(\frac{\partial d_{1j}(P)}{\partial \xi_{ji}} + \frac{\partial d_{2j}(P)}{\partial \xi_{ji}}\right) = \frac{\partial k(\xi_{j1}, \xi_{j2})}{\partial \xi_{ji}}, i, j \in \{1,2\}. \tag{9b}$$

Conventionally, the left-hand side of each of the FOCs is the marginal benefit of investment (via increase of the demand for corresponding product), whereas the left-hand side is its marginal cost. Assuming that investment affects quality linearly, the marginal benefit of investment is simply marginal profit with respect to quality of the good that is being improved.

## 3.2 Post-merger equilibrium

After merger, the firms' second stage profits can be written as

$$\begin{aligned} \pi_{AB}(\Delta) &= s_{11}^* d_{11}(P) + p_1^* d_{12}(P) + q_1^* d_{21}(P) \\ \pi_{A_2}(\Delta) &= p_2^*\left(d_{21}(P) + d_{22}(P)\right); \\ \pi_{B_2}(\Delta) &= q_2^*\left(d_{12}(P) + d_{22}(P)\right). \end{aligned}$$

The firms thus maximize

$$\pi_{AB}(\Delta) - (k(\eta_{11}, \eta_{12}) + k(\xi_{11}, \xi_{12}) - f(\eta_{11}, \eta_{12}, \xi_{11}, \xi_{12})),$$
$$\pi_{A_2}(\Delta) - k(\eta_{21}, \eta_{22}),$$
$$\pi_{B_2}(\Delta) - k(\xi_{21}, \xi_{22}).$$

Here, $f : \mathbb{R}_+^4 \to \mathbb{R}_+$ denotes potential efficiency of the merger in terms of investment cost.

For the two non-merging firms, only the equilibrium profits change, but not the form of FOCs as represented by (9a) and (9b). For the merging firms, the investment externality in compatibility of all-own product is internalised. For example, the FOC with respect to the investment $\eta_{11}$ is

$$s_{11}^* \frac{\partial d_{11}(P)}{\partial \eta_{11}} + p_1^* \frac{\partial d_{12}(P)}{\partial \eta_{11}} + q_1^* \frac{\partial d_{21}(P)}{\partial \eta_{11}} = \frac{\partial k(\eta_{11}, \eta_{12})}{\partial \eta_{11}} - \frac{\partial f}{\partial \eta_{11}}. \tag{10}$$

Again, we see that the condition equates marginal benefit from investment in terms of increasing the demand (and therefore revenue) and costs. The FOC with respect to investment $\xi_{11}$ is completely analogous. In fact, if $k$ and $\delta_{11}(\eta_{11}, \xi_{11})$[5] are symmetric with respect to their two arguments, then $\eta_{11} = \xi_{11}$ in post-merger equilibrium.

On the other hand, a possible negative externality on quality of or demand for other products, is also internalised. For example, the FOC with respect to $\eta_{12}$ is

$$s_{11}^* \frac{\partial d_{11}(P)}{\partial \eta_{12}} + p_1^* \frac{\partial d_{12}(P)}{\partial \eta_{12}} + q_1^* \frac{\partial d_{21}(P)}{\partial \eta_{12}} = \frac{\partial k(\eta_{11}, \eta_{12})}{\partial \eta_{12}} - \frac{\partial f}{\partial \eta_{12}}. \tag{11}$$

## 3.3 Comparison

We now discuss two *primary* or direct effects of the merger identified by the differences in FOCs. The *first* such effect results from the fact that in choosing compatibility investment the merged firm takes into account the effect of its choice on the profit from two components rather than one as pre-merger.

For the investment into the bundled solution, the difference between [lhs of] (10) and (9a), at pre-merger prices and pre-merger investment levels, is $q_1^* \left( \frac{\partial d_{11}(P)}{\partial \eta_{11}} + \frac{\partial d_{21}(P)}{\partial \eta_{11}} \right)$. The first term here is positive and the second depends on the form of the mapping from investment to quality as well as on the form of the mapping from quality to demand. In particular, if either investment is characterised by negative externality on the quality of other products, or demand is characterised by business stealing effect of quality increase, the second term may be negative. It is reasonable to assume, however, that the "net" effect of investment on demand must be positive, $\frac{\partial d_{11}(P)}{\partial \eta_{11}} > \left| \frac{\partial d_{21}(P)}{\partial \eta_{11}} \right|$. At pre-merger investments and prices, then, the profit derivative would be positive, indicating,

[5]We intentionally suppress all other arguments of the function that maps investments into the compatibility quality of the product A1B1.

quite intuitively, that the investment has to increase. Quasiconcavity of profits in each investment is sufficient for this result.

For the investment into the mix-and-match solution, the difference between [lhs of] (11) and (9a), at pre-merger prices and pre-merger investment levels, is $q_1^* \left( \frac{\partial d_{11}(P)}{\partial \eta_{12}} + \frac{\partial d_{21}(P)}{\partial \eta_{12}} \right)$. Both terms here are negative if there is a negative externality and business stealing effect discussed in the previous paragraph. At pre-merger investments and prices, then, the profit derivative is negative, indicating that the investment has to decrease. Again, quasiconcavity of profits is sufficient for this result.

The *second* primary effect (as identified by the difference in FOCs) is the potential investment cost efficiency. Due to the synergies in investment, it may be that marginal costs are reduced as a result of the merger ($\frac{\partial f}{\partial \eta_{11}} > 0$), thus providing incentive to increase investment.

There are of course secondary effects that go through the changes in prices, which are due to merger and may overturn the direct effect of internalisation. To isolate the primary and secondary effects, one may evaluate the investment that would have resulted in merger case at pre-merger prices. The difference with pre-merger situation is due to the primary effect only.

An interesting benchmark to consider in this case is the symmetric demand with independent goods. From previous section, we know that this shuts down both competition and price discrimination effect, so that the merger only results in Cournot effect, i.e. $s_{11}^1 < p_1^0 + q_1^0$. In this case, the difference in profit derivatives wrt $\eta_{11}$ post and pre-merger becomes

$$s_{11}^1 \frac{\partial d_{11}\left(P^1\right)}{\partial \eta_{11}} - p_1^0 \frac{\partial d_{11}\left(P^0\right)}{\partial \eta_{11}} + \frac{\partial f}{\partial \eta_{11}}, \tag{12}$$

if we also assume no business stealing and no investment externalities across products. Even in this restrictive case, it is not warranted that the investment effect outweighs the price effect. In particular, note that the derivative in question is

$$\frac{\partial d_{11}(P)}{\partial \eta_{11}} = \left( \frac{\partial d_{11}}{\partial \delta_{11}} + \frac{\partial d_{11}}{\partial s_{11}} \frac{\partial s_{11}}{\partial \delta_{11}} \right) \frac{\partial \delta_{11}}{\partial \eta_{11}}.$$

Here, $\frac{\partial \delta_{11}}{\partial \eta_{11}}$ as a function does not change as a result of merger, and neither does $\frac{\partial d_{11}}{\partial \delta_{11}}$. However, both $\frac{\partial d_{11}}{\partial s_{11}}$ and $\frac{\partial s_{11}}{\partial \delta_{11}}$ potentially change. A sufficient condition for the effect via investment to not be overturned by the price effects is that $\frac{\partial d_{11}}{\partial s_{11}}$ and $\frac{\partial s_{11}}{\partial \delta_{11}}$ do not change much due to merger. More precisely, the investment of the merging firms rises post-merger if expression (12) is positive.

As this simple benchmark illustrates, even though we know the directions of equilibrium price changes due to the merger for sufficiently symmetric demand systems, changes in the derivatives are dependent on a particular demand system (as well as on the particular mapping of investment into quality). Therefore, it is only possible to state general results in terms of various effects as discussed below.

### 3.4 Summary of effects

In a setting with investment in compatibility, a merger results in partial internalization of two pre-merger externalities: (i) the standard pricing externality associated with the independent pricing of complementary – the well-known *Cournot effect*; and (ii) the externality associated with investment that benefits other firms that results in *free-riding* and underinvestment problem. The free-riding problem arises because investments by a component seller into compatibility with a complementary component benefit not only the sales of the former component, but also the sales of the latter one.

When composite goods—systems—are substitutes, the merger also has a third, *competition relaxing*, effect. When systems are independent, the standalone prices of the merging firms remain at their pre-merger levels post-merger, so the bundled discount is solely due to internalisation of Cournot effect by lowering bundled price. With competition, however, the merging firms have an incentive to raise their standalone prices relatively to pre-merger level, at the same time lowering the bundled price less than without competition. The resulting bundled discount is larger (in relative terms) with competition. This is because, for the integrated firm, the decrease in the demand for systems that are mixed-and-matched using the standalone components is more than compensated by the increase in the demand for the system provided solely by the merged firm.

Finally, when there are asymmetries in the demand such that merging firms would prefer pre-merger to set different prices for at least one component depending on which system it is a part of, there is a fourth, *price-discrimination*, effect. It acts to increase bundled discount whenever pre-merger discriminatory price is lower for mix-and-match solution, and makes bundled discount smaller in the opposite case.

The interaction of the four effects is what drives the results for any particular setting. We examine this interaction in a linear demand system in the next section. Solving the model explicitly also allows us to analyse the effects of merger on consumer welfare and the ability and incentive of the merged firm to engage in foreclosure.

## 4 Example: linear demand a la Symeonidis

As an illustration, we consider a linear-quadratic utility of Shubik-Levithan type as generalized by Symeonidis (2004):

$$\sum_{ij}\left(d_{ij}-\frac{d_{ij}^2}{a_{ij}^{2\gamma}}\right)-c\sum_{ij\neq kl}\frac{d_{ij}d_{kl}}{a_{ij}^{\gamma}a_{kl}^{\gamma}},$$

where $c\in[0,2]$ is the parameter characterising the degree of substitutability between composite goods; $a_{ij}>0$ are parameters characterising quality of each system, and $\gamma$ is a parameter characterising the importance of quality for the consumers (relative to the units of numeraire good). Solving consumer problem, we get the following inverse demand system:

$$1 - \frac{2d_{ij}}{a_{ij}^{2\gamma}} - \frac{c}{a_{ij}^{\gamma}} \frac{d_{-ij}}{a_{-ij}^{\gamma}} = s_{ij},$$

where by $-(ij)$ we denote (the sum of) all the (double) subscripts other than $ij$.

Inverting this system and augmenting quality with compatibility part $u_{ij} := (a_{ij} + \delta_{ij})^{\gamma}$, where $\delta_{ij}$ is a parameter characterising the degree/ quality of compatibility of the components that make the product $A_i B_j$, we have

$$d_{ij} = \frac{u_{ij}}{2-c} \left( u_{ij} \left(1 - s_{ij}\right) - \frac{c}{3c+2} \sum_{kl} u_{kl} \left(1 - s_{kl}\right) \right).$$

For simplicity, we assume that the investments affect the compatibility quality linearly. The quality $\delta_{ij}$ of the product $A_i B_j$ is the sum of the two investments: $\eta_{ij}$, the investment of the producer of component $A_i$ into compatibility with component $B_j$; and $\xi_{ji}$, the investment of the producer of component $B_j$ into compatibility with component $A_i$, $\delta_{ij} = \eta_{ij} + \xi_{ji}$. The cost of investment is assumed additive quadratic for simplicity. For example, $k\left(\eta_{i1}, \eta_{i2}\right) = \frac{1}{2} k \left(\eta_{i1}^2 + \eta_{i2}^2\right)$, where we abuse notation and denote the investment cost parameter by the same letter as the cost investment function. The expression for $\xi$ is analogous. Finally, we assume away any cost-related merger efficiency, $f\left(.\right) \equiv 0$.

The sets of FOCs resulting from these specifications can be solved numerically for a point in the space of parameter values, $\{a, c, \gamma, k\}$. In our simulations, we distinguish between two scenarios: (i) with investment, which is the model presented above, and (ii) without investment, which is the same model with $\delta_{ij} \equiv 0$. The pictures are plotted for $\gamma = \frac{1}{2}$.

**Observation 1.** When the firms are allowed to invest into compatibility, they tend to provide smaller bundled discount than in the scenario without investment. This investment effect is stronger when the composite goods are closer substitutes.

**Observation 2.** The overall investment into compatibility is higher post-merger. The increase of overall investment is smaller when the composite goods are closer substitutes.

**Observation 2a.** The investment into compatibility of the own product of the merging firms is higher post-merger.

**Observation 2b.** The investment into compatibility of the component of the post-merger integrated firm with the component of the standalone firm is lower post merger. The drop of this kind of investment is higher when the composite goods are closer substitutes.

**Observation 3.** Consumers benefit from merger more (or suffer less) when the firms are allowed to invest into compatibility compared to the scenario without investment. The merger-induced change in consumer surplus is U-shaped as a function of substitutability.

**Observation 4.** The profit of the standalone firms is lower post-merger. The decrease in profit is larger when the firms are allowed to invest into compatibility, compared to the scenario without investment.

**Observation 5.** The incentive of the integrated firm to foreclose standalone rivals by underinvesting into compatibility with their components and overinvesting (compared to no-forclosure equilibrium) into compatibility of the own product is bigger when the composite goods are closer substitutes.

More informally, we note a trade-off that introducing compatibility-improving investment brings to the analysis. On one hand, solving free-riding problem in investment for the merging parties benefits consumers; on the other hand, it puts the rivals in a disadvantaged position that in extreme cases may lead to foreclosure.

In the following, we illustrate our results graphically and discuss them in greater detail. Although the graphs here are plotted for the utility function used in Symeonidis (2000), qualitatively similar results obtain with another linear-quadratic utility used by Choi (2008).

# 5 Varying substitutability $c$

In this section, we analyse how a merger affects component and system prices, investments, profits and consumer surplus (CS) for different degrees of substitutability among the four systems. For now, we assume that the merger does not result in a foreclosure of any of the two independent firms. We will relax this assumption later.

## 5.1 Prices

As summarized in the previous section, standalone prices of the merging firms increase relative to pre-merger, whereas the price of the bundle decreases. This is illustrated in Figure 1 for the scenario without investment, where the prices post-merger are plotted in per cent deviations from the pre-merger price as a function of parameter $c$. Deviations of standalone prices of the merging firms are depicted by the violet curve, deviations of the prices of the standalone firms are depicted by the green curve, and the deviations of the bundle price are depicted by the blue curve.

We observe that the standalone firms react by reducing their price relative to pre-merger in our setting without investment, and this reduction has a U-shape as a function of $c$. Both deviations of standalone prices of merged firms and deviation of bundle price are increasing in $c$, whereby standalone prices increase

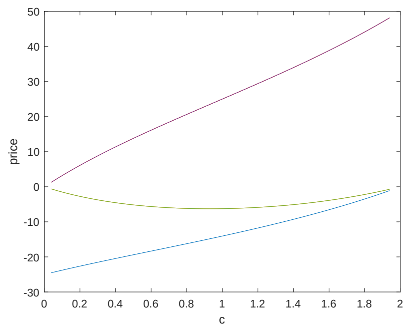


Figure 1: Merger-induced price changes without investment, % of pre-merger price

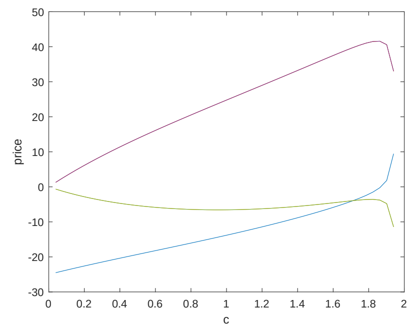


Figure 2: Merger-induced price changes with investment, % of pre-merger price

faster, reflecting the competition relaxing effect of the merger discussed above. The magnitude of the bundle price deviation at $c = 0$ (which is also equal to bundle discount at this point) characterises Cournot effect. The distance between blue and violet curves then characterises the sum of the two effects.

The same price deviations in the model with investment are described in Figure 2. Here, the third, investment effect kicks in at higher levels of $c$ and pushes the bundle price above the prices of standalone competitors and eventually above the pre-merger price. The same effect also puts downward pressure on standalone prices of all firms at high levels of $c$. We look at the investment effect in more detail when we inspect the bundled discount.

It is important to keep in mind that Figures 1 and 2 show deviations rather than levels of prices. The price levels are all decreasing in $c$ reflecting more intense competition that arises when the composite goods are closer substitutes. This is illustrated in appendix in Figure 15.

Next, we plot the bundled discount as a function of $c$, in scenarios with (blue curve) and without (red curve) investment - see Figure 3.

For low and medium values of substitutability parameter ($c \leq 1.5$), the bundle discount exhibits very similar relations to parameter $c$ in the two scenarios (with and without investment). For higher values of $c$, however, without investment into compatibility, bundled discount continues to grow as the composite products become closer substitutes; with investment, the bundled discount goes down and eventually drops to zero in the limit.

The bundled discount can be explained, similarly to the price changes resulting from merger, by three effects. Firstly, there is a *Cournot* effect that in case of independent goods ($c = 0$) solely determines the level of bundled discount. Since at this point the merged firm is effectively a monopolist post-merger, this level indicates pure efficiency of removing double marginalisation from pricing two complement components jointly.

Second, for $c > 0$ competitive pressure between systems kicks in, making

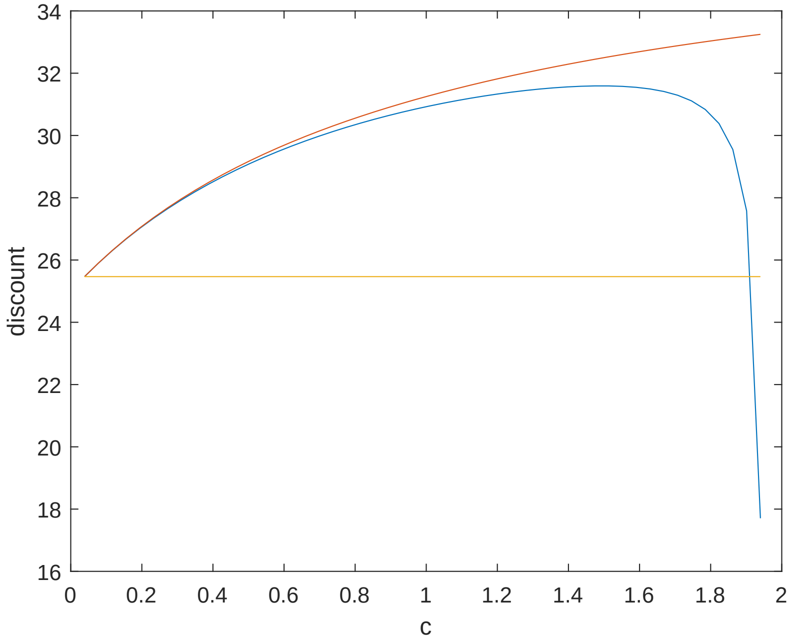


Figure 3: Bundled discount in %

it optimal for the merging parties to relax this pressure by decreasing prices of standalone components less than the price of the bundle, thus providing higher bundled discount with higher $c$. This *competition relaxing* effect can be quantified by the distance from the red curve to the yellow line drawn at the level of discount for independent goods. This effect is positive and increasing in $c$.

Third, the higher competitive pressure associated with higher $c$ provides an incentive to differentiate the composite products in terms of quality. In particular, the gap between investment into compatibility of own components and investment into compatibility with components of other firms becomes relatively more important as $c$ increases, because all prices become smaller (and therefore costlier to decrease further). The *investment* effect can be quantified by the distance between the red and the blue curves. It is negative and increasing in $c$ by absolute value. When goods are independent ($c = 0$), the investment difference does not play any role in determining bundled discount, since the latter is only determined by Cournot effect. At the other extreme, when goods are almost perfect substitutes, ($c \geq 1.95$), the investment effect is so large that it completely offsets the other two effects, so that the bundled discount is zero.

The investment effect can be intuitively thought about in terms of nominal (monetary) and effective (quality-adjusted) discount. Consumers care for both quality and money; therefore certain quality difference is equivalent to some difference in prices. Consequently, there are two ways to provide effective discount: (i) decrease bundled price relative to the sum of standalone prices, or (ii) invest more into compatibility of own components while investing less into compatibility with components of other firms. With higher substitutability, prices go down, so the quality channel becomes more important. In the limit of $c = 2$, price is equal to marginal costs, which in our parametrization is zero - price discount is not effective and only the discount (premium) in terms of quality is provided.

## 5.2 Investment into compatibility

One of the robust and novel results of our analysis is the finding that the merging firms have incentive to reduce their investment (relative to pre-merger) into compatibility of their components with components of the standalone firms. The total investment in the industry, however, increases after merger, because the merging firms have a strong incentive to increase investment into compatibility of their own components.

The merger-induced relative increase in overall investment is decreasing in $c$ (this is illustrated in Figure 17 in the appendix). This pattern is a result of interplay of two forces. On the one hand, there is a direct effect of internalising the free-riding externality, which is positive and in our specification increasing in parameter $c$ - see Figure 4. This effect is reflected in the distance between the blue curve, the total investment pre-merger, and the yellow curve, the total investment in a benchmark where all prices are fixed at pre-merger levels, but the investment decision of the two merging firms are taken in coordinated fashion.

On the other hand, there is an indirect effect on investment incentives through price coordination. This effect is positive for low values of $c$ and turns negative and increasing by absolute value for higher values of $c$, as reflected by the distance between the yellow curve and the red curve, the total investment post-merger. As competition-relaxing effect of merger grows in relative terms with higher $c$, it also suppresses overall investment more. In the limit, the direct and indirect effects of merger on investment cancel out (around $c = 1.95$ and above).

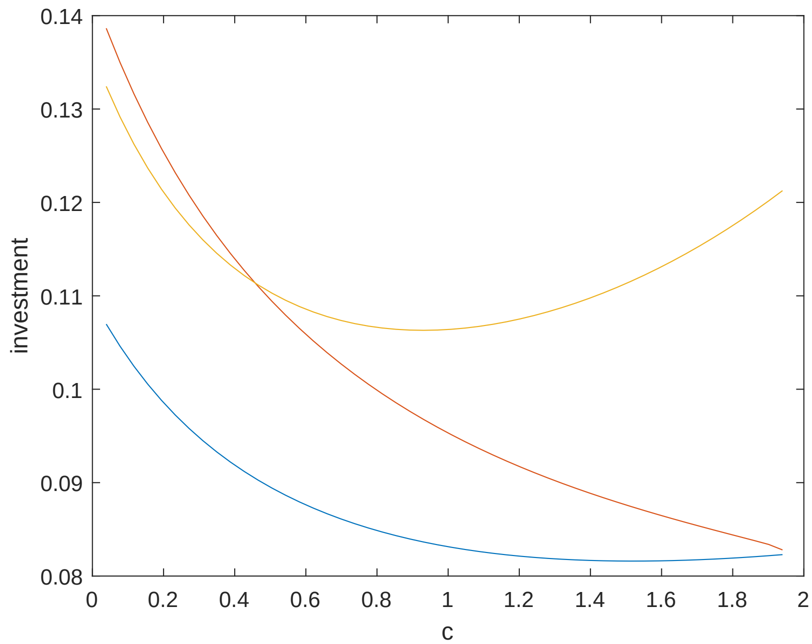


Figure 4: Overall investment pre-, post-merger and in the benchmark

In the appendix (Figure 18) we show that the investment of the merging parties in the compatibility of their own products exhibits roughly the same pattern as overall investment and can also be attributed to the two effects discussed above. The exception is a spike in investment for values of around $c = 1.87$ and above that we discuss after looking at all other kinds of investment.

In the next panel, we plot how all four kinds of investment: (i) investment into the compatibility of the own product of the merging firms [II-investment], (ii) investment into compatibility of the component of the post-merger integrated firm with the component of the standalone firm [IS-investment], (iii) investment into compatibility of the component of the standalone firm with the component of the post-merger integrated firm [SI-investment], and (iv) investment into compatibility the components of the standalone firms [SS-investment].

The red curves characterise post-merge values; the blue curves characterise pre-merger values.

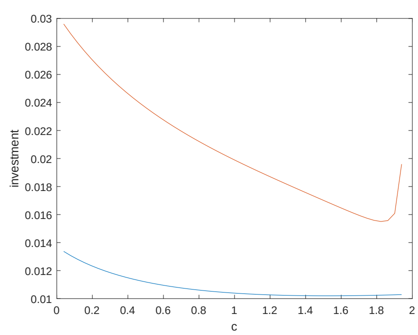


Figure 5: II-investment

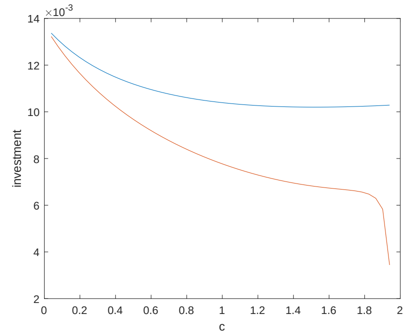


Figure 6: IS-investment

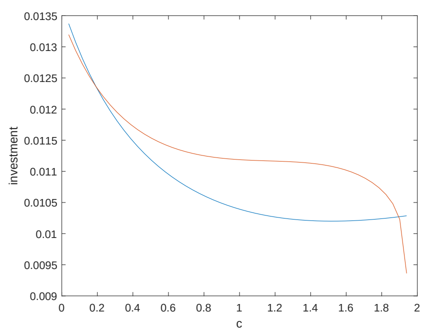


Figure 7: SS-investment

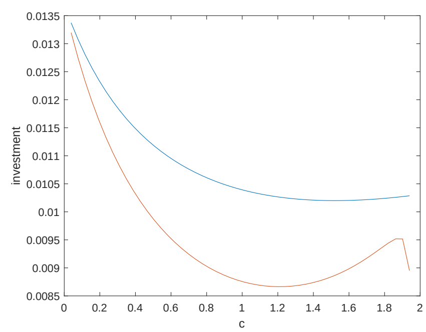


Figure 8: SI-investment

We observe that the II-investment is always higher post merger, which reflects mostly the direct effect of internalising the free-riding externality for the two merging firms. The IS- and SI-investments are lower post-merger, which characterises the incentive of the merged firm to curb compatibility of its component with that of the standalone firms and the reaction of standalone firms to such degradation of compatibility. The SS investment is higher post-merger for the most of the set of admissible values of c, but it is lower for very low and very high c.

The spike in II-investment and simultaneous drop in all other kinds of investment around $c = 1.87$ is related to the fact that around this point the bundle price turns from being below the pre-merger price for the lower values of $c$ to being higher than pre-merger price for higher values of $c$. Further increase in the merger-induced rise of bundle price (for higher $c$) makes investment gap sufficiently attractive to rapidly increase II-investment while rapidly decreasing IS-investment. The standalone firms react by decreasing SS- and SI-investment.

### 5.2.1 Consumer surplus

In Figure 9, the blue curve stands for the CS difference under investment scenario; the red curve is for the CS difference without investment.

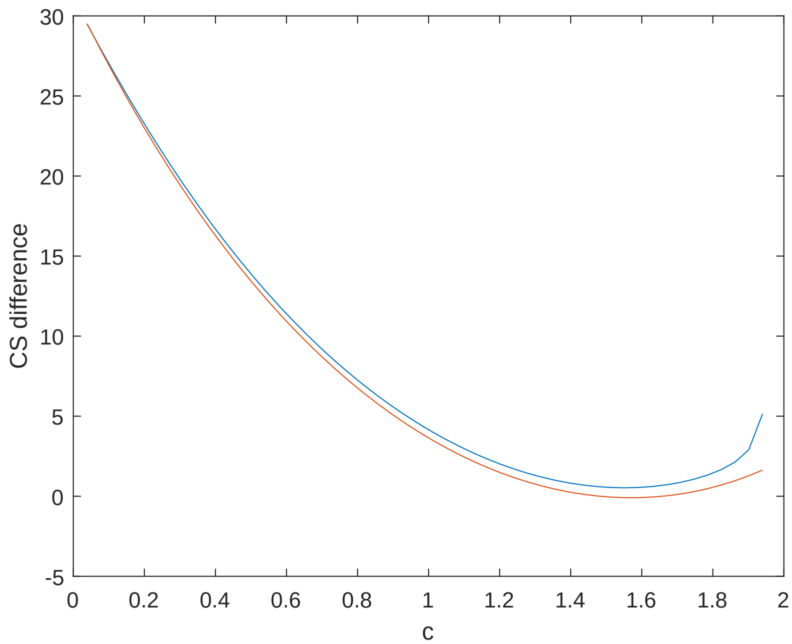


Figure 9: Merger-induced change of consumer surplus, % of pre-merger level

The blue curve is always above the red one. This means that a merger increases CS more in the scenario where firms also invest in compatibility compared to the scenario where they only set prices. This is a robust result. At the same time, for the values of substitution parameter $c$ around 1.6, the merger does not benefit consumers in no investment scenario, but does benefit them in investment scenario. This result is specific to the parameterizations we chose. The U-shape of the change of consumer surplus is apparently specific to the demand system that we chose.

# 6 Foreclosure

In this section, we study the possibility of the merged firm to foreclose its rivals. Firstly, we look at the equilibrium that would result in case foreclosure were successful. For the symmetric demand system, after foreclosure we have only one composite good, the utility is

$$d_{11} - \frac{d_{11}^2}{a_{11}^{2\gamma}}.$$

Solving consumer problem, we get the following inverse demand function:

$$1 - \frac{2d_{11}}{a_{11}^{2\gamma}} = s_{11}.$$

Profit maximization in the second stage results in monopolistic price $s_{11} = \frac{1}{2}$. The profit is

$$\frac{(a_{11} + \delta_{11})^{2\gamma}}{8} - \frac{k}{2}\left(\xi_{11}^2 + \eta_{11}^2\right).$$

Maximizing the profit results in optimal investment implicitly defined by

$$4k\xi_{11} = \gamma\left(a_{11} + 2\xi_{11}\right)^{2\gamma-1}.$$

## 6.1 Unintentional foreclosure

Next we analyse the conditions under which foreclosure results even when the merged firm does not act strategically in order to induce it. The necessary condition for such foreclosure is that the fixed costs of the standalone rival are smaller than her (operational) profit before merger, but greater than her profit after merger. This implies that a drop in profit of the standalone rival after merge is a (weaker) necessary condition for unintentional foreclosure.

In Figure 10, we plot the change in profit of a standalone firm for the no investment scenario (red curve) and with investment (blue curve).

We can see that the result of profit difference being larger (by absolute value) with investment is robust to varying substitutability parameter. We also observe that the drop of standalone firm's profit has a U-shape as a function of substitutability parameter $c$ in both scenarios, but drops quickly at large values of $c$ in the investment scenario. This drop is induced by the sharp deterioration of compatibility of mix-and-match composite goods relative to compatibility of the bundled good.

The U-shape is intuitive, because at both extremes the standalone rivals should not be affected by the merger. When goods are independent, the profit does not depend on the actions of competitors. When goods are perfect substitutes (in the no investment scenario), there is marginal cost pricing both pre-merger and post-merger, so the merger again does not change the profit of the standalone firms. In the middle range of parameter $c$, standalone firms react by lowering their prices in response to coordinated pricing of merging parties. The market shares of standalone firms decrease as well, because consumers switch to cheaper bundled good. As a result of lower prices and lower market shares, profit pos-merger is lower as well.

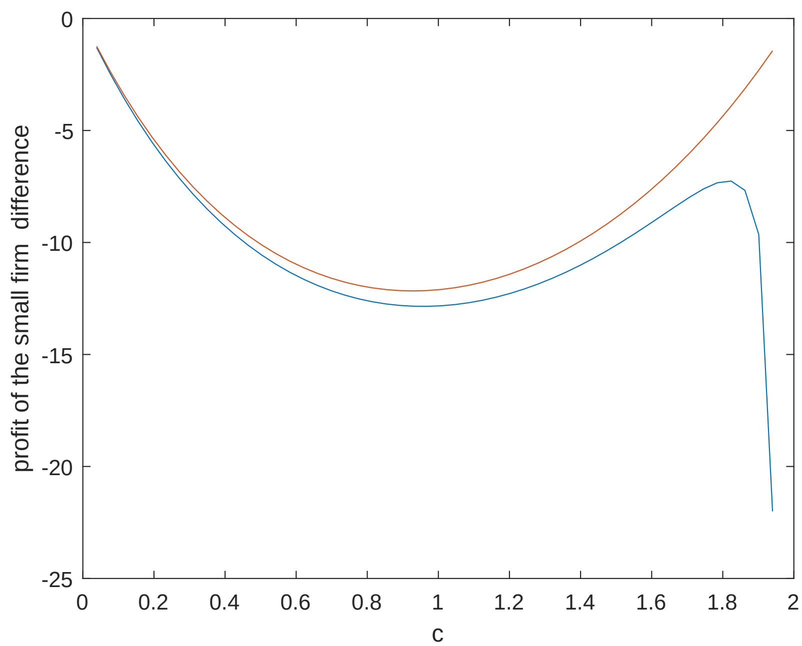


Figure 10: Merger-induced profit change for a standalone firm, % of pre-merger profit

## 6.2 Intentional foreclosure

Intentional foreclosure may arise in our model when the merged firm manipulates its investment into compatibility to lower rivals' profit sufficiently low so they cannot cover their fixed costs.

Ability to do so, in our case, is closely related to the level of fixed cost as well as to the sensitivity of rival's profit to changes in compatibility. The higher the fixed costs are and the more sensitive the rival profit to increases of the merged firm's investments into compatibility, the greater is the ability to foreclose.

The incentive for foreclosure may be characterised by the difference in profits that the merged firm receives with and without foreclosure. In Figure 11, we plot the difference between the highest foreclosure profit and Nash equilibrium profit in absolute terms.

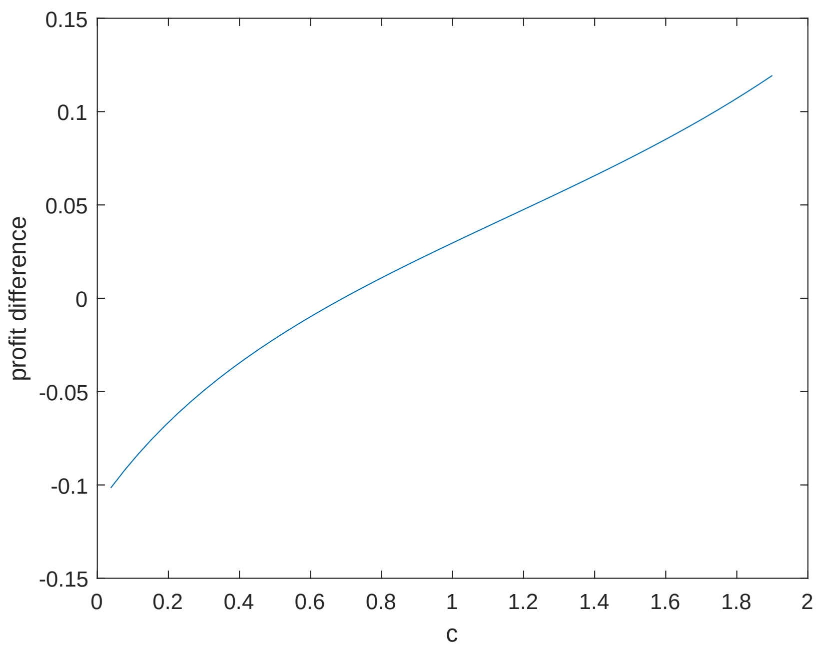


Figure 11: Foreclosure incentive

Below about $c = 0.72$, intentional foreclosure is not profitable. For higher values of $c$, the percentage difference between foreclosure and non-foreclosure profits grows exponentially, reaching almost 900% at $c = 1.94$. This profit difference that characterizes the incentive to foreclose is not informative about ability to foreclose. Foreclosure is only possible for sufficiently high fixed costs even if the incentive is very strong.

We also look at the level of consumer surplus pre-merger (blue curve), post-merger (red curve), and with successful (unintentional) foreclosure (yellow curve) in Figure 12.

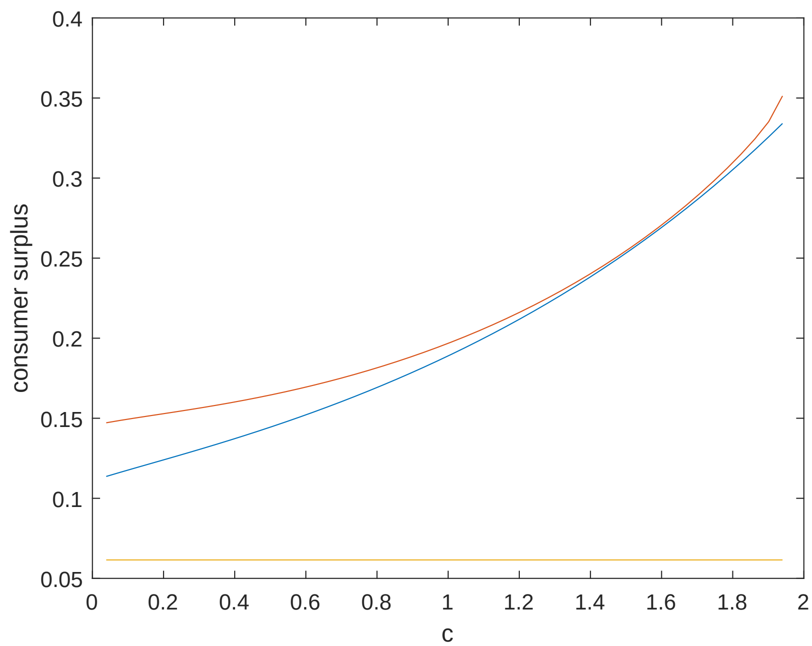


Figure 12: Consumer surplus levels with and without foreclosure

We observe that foreclosure always results in lower consumer surplus than no foreclosure situation.

# 7 Asymmetries

We vary the degree of asymmetry $x$ in the following sense: we put $a_{21} = a_{22} = 1 - x$, whereas $a_{11} = a_{12} = 1 + x$. I.e., we change the "basic quality" of the composite goods in a way to preserve the average quality of the demand system. In particular, we increase the quality of the goods that include component $A_1$ and decrease that of the goods that include component $A_2$. We fix the substitutability parameter at $c = 0.5$.

In Figure 13, the blue curve stands for the difference between CS post- and pre-merger under investment scenario; the red curve is for the CS difference without investment.

We observe that the result from the symmetric setting extends to the asymmetry considered: the merger-induced increase in CS is larger in investment scenario compared to no investment scenario. Moreover, the (relative) benefit of consumers from merger is larger when the asymmetry is larger.

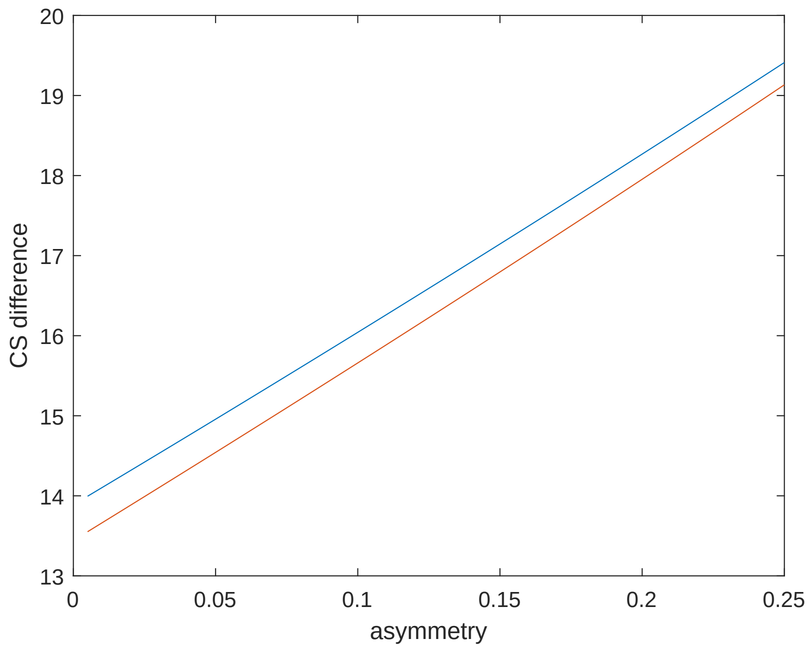


Figure 13: Merger-induced change in consumer surplus, % of pre-merger level

In Figure 14, the blue curve stands for the difference between disadvantaged standalone firm's profits post- and pre-merger under investment scenario; the red curve is for the profit difference without investment.

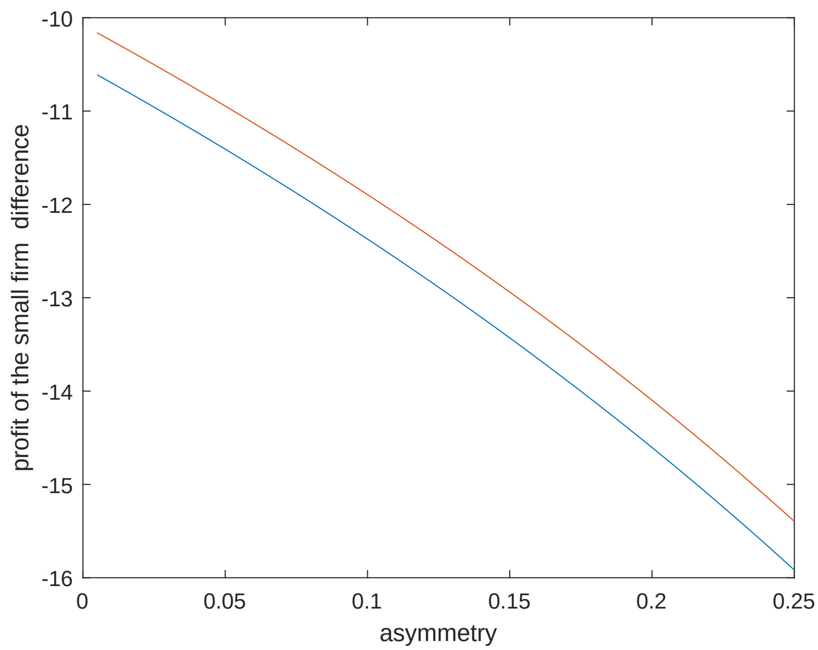


Figure 14: Merger-induced change in the profit of the disadvantaged standalone firm, % of pre-merger level

We again see that the result from the symmetric setting extends to the case of asymmetries. Further, the drop in the profit of the disadvantaged firm is higher when the asymmetry is stronger.

We also note that the increase in overall investment due to merger is smaller when the firms are more asymmetric; also the decrease of IS-investment is smaller by absolute value with more asymmetry. We do not provide graphic representation of these results here.

# 8 Conclusion

We have identified a number of general effects that a merger between producers of complementary products (components) brings to life. We have also focused on a situation in which producers may invest into compatibility between their components and components of other producers. Overall, we have exposed three price effects (Cournot, horizontal, price discrimination) and an investment effect (internalisation of positive and negative externalities in ones's investment decision).

We have further numerically analysed and checked robustness of our results to varying parameters for a specific linear demand system.

Though many of our results are limited by demand linearity, strict complementarity and the fixed number (four) of firms pre-merger, we believe that they hold, to an extent, in more general settings that relax these assumptions.

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# 9 Appendix

## 9.1 Figures

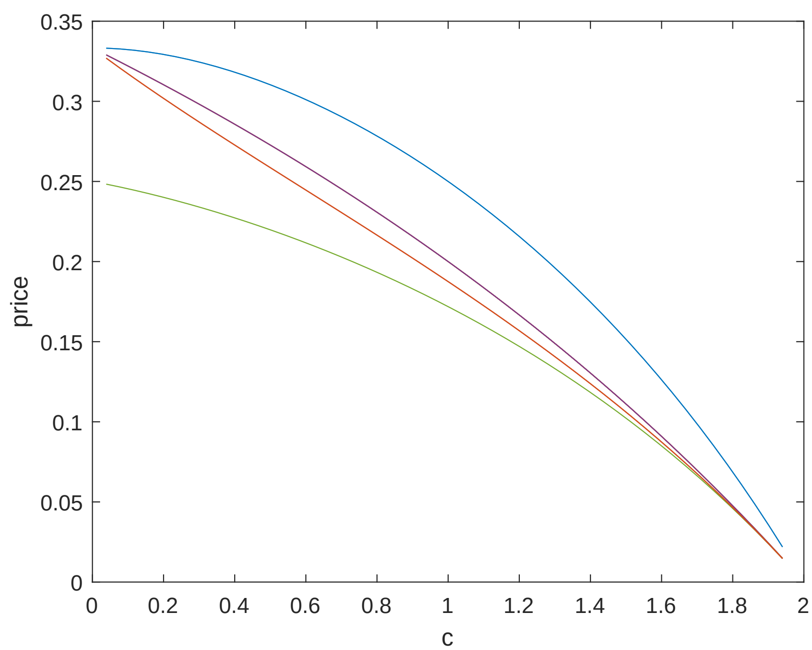


Figure 15: Prices before and after the merger, no investment case

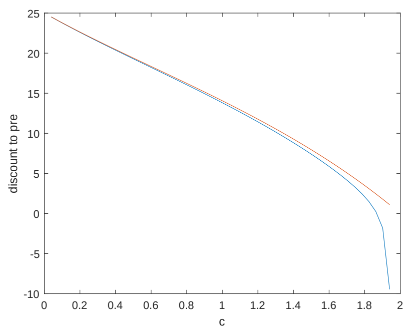


Figure 16: Discount relative to pre-merger prices,%

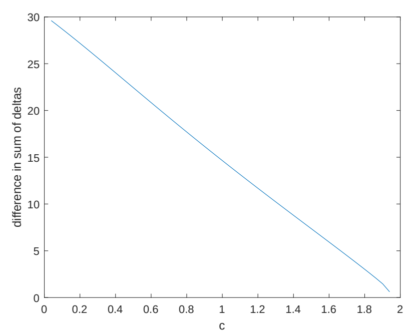


Figure 17: Merger-induced change in total investment, % of the pre-merger investment

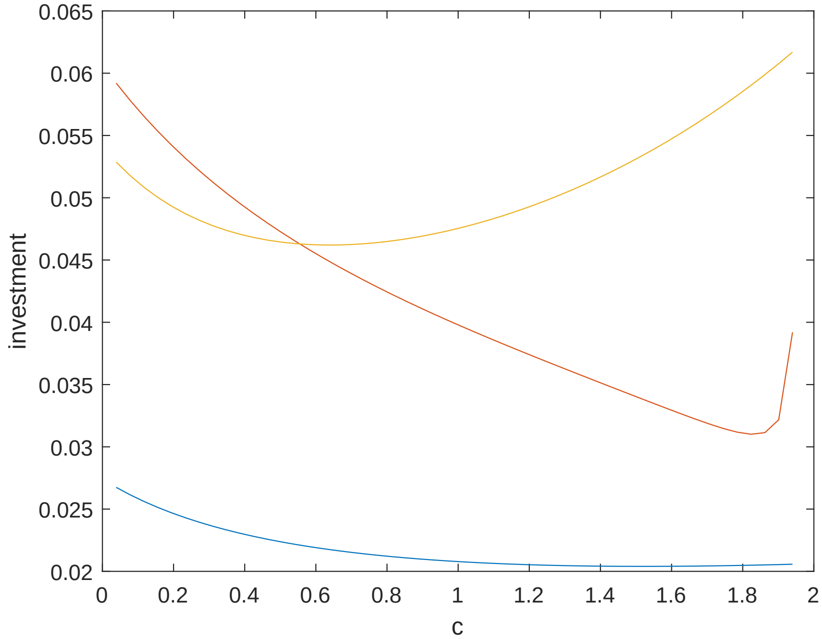


Figure 18: II-investment pre-, post-merger and at the benchmark