Welfare implications of strategic outsourcing in oligopolistic markets

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Abstract

This paper shows the strategic aspects of outsourcing in duopolistic markets, where the production choice is driven by the different costs of integrated production and outsourcing. Thus, the resulting production structure depends on the relationship of the costs, i.e. the difference of fixed costs versus the difference of marginal costs. However, the choice of the firms affects also the consumer, since the output price is affected by the costs. Therefore, we also analyze the welfare implications of the different constellations concerning the production strategies. If the optimal decisions of the firms are characterized by different production modes, this constellation is always superior to a constellation with symmetric strategies. On the other hand, if the optimal decisions of the firms are characterized by symmetric production modes, this constellation can be inferior or superior to a constellation with asymmetric strategies.

Keywords: Strategic Outsourcing, Oligopoly, Welfare

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1 Introduction

From a firm's perspective, outsourcing, i.e. the acquisition of formerly self-produced inputs from an external independent specialized supplier, is viewed as the possibility to focus on core competencies, to gain a specialized knowledge or to avoid high domestic labor costs. Thus, it is one possibility to produce in a cheaper way. Following Holl (2008), the main reason for outsourcing is the realization of lower average production costs. However, this can be done by two ways. Due to the specialization of the input producer its marginal costs can be lower than the marginal costs of the final good firm. But this outsourcing advantage can be (partly) set off by transaction costs or investments for monitoring the product quality, which are borne by the final good producer. On the other side, also higher marginal production costs of the specialized input supplier compared to the marginal costs of the final good producer are possible, but now the final good producer maybe saves investments costs.[1] In both cases outsourcing becomes beneficial since it can lead to lower average production costs for the final good firm compared to an integrated production.

The important role of outsourcing can be seen in the mobile communication and automobile industry. Nokia outsourced 20% of its mobile production (Economist, 2002). Sinn (2005) showed that 88% of the production volume of the Porsche Cayenne is procured externally. For the overall automobile industry the Fraunhofer Institute and Mercer (2004) estimated that by the year 2015 automobile sub-contractors will be handling up to 80% of the development and production, i.e. the production stages with the highest fixed costs, whereas the manufacturers will focus on the post-production stage, e.g. sales, since investments at that stage mean higher profits with less capital input.[2]

In this paper we assume that outsourcing becomes attractive because of fixed cost savings, but is also associated with higher marginal costs than

[1] The production choice is therefore made by comparing the overall in-house production costs with the external procurement costs, where transaction or monitoring costs are included. For instance, in Williamson (1975, 1986) outsourcing is explained by the transaction cost thesis, where lower transaction costs favour outsourcing.

[2] The tendency towards external procurement is also documented in Hummels et al. (1998, 2001) and Yeats (2001).

the integrated production. Thus, we see the organizational choice as an investment choice, where outsourcing stands for a long-term externalization of certain production parts. This argument plays an important role in high-investment sectors such as the automobile or aircraft industries, since autonomous input suppliers can divide their fixed costs among various buyers, while an in-house producing company will typically produce the parts only for himself. Therefore, the input firm realizes lower average costs due to the fixed cost regression compared to the final good firm and outsourcing becomes beneficial.

Since the decision concerning the production mode influences the costs and thus the market price, other participants in that industry are also affected. The other firms will react to this by adapting their own production mode to save or improve their market positions. Thus, the organizational choice becomes an instrument of strategic interaction between participants in an industry.

We analyze these interactions and the resulting welfare implications. This is an interesting research question since in the public debate outsourcing is seen as a reason for job losses, lower wages and more unequal income distribution, i.e. outsourcing has only negative consequences. However, from an economic policy point of view, the overall welfare is a relevant measure and after knowing the resulting implications, maybe a redistribution mechanism can be implemented to compensate the possible negative consequences.

The following questions will be answered in this paper: First, which market outcomes and market structures result from the production choices? Second, is rational behavior by the firms the best behavior from a welfare point of view?

As outsourcing prevents fixed costs but also entails higher marginal costs than the in-house production, the company is faced with a trade-off between investment costs saving and additional marginal cost payments. When the marginal cost disadvantage of external procurement, relative to the fixed costs, is sufficiently low (high), outsourcing (integration) becomes the dominant production structure. A medium level of the marginal costs disadvantage constitutes an asymmetrical constellation. Regarding the second question, we demonstrate via comparative statics, whether the resulting market constellation for given costs is superior or inferior to other production structures. We find that in the case of symmetric production modes this constellation is always superior compared to the other constellation of symmetric production choices. Additionally, we also find that for given costs a constellation in different production strategies is always superior to a constellation with equal production strategies, whether the firms use outsourcing or an integrated production structure. On the other hand, a constellation of equal strategies can be inferior or superior to a constellation with different production choices. Therefore, profit maximizing behavior by choosing outsourcing can lead in some cases to the preferred constellation from the welfare point of view and outsourcing is not necessarily as bad as it is seen.

The analysis is structured as follows. Section 2 reviews the existing literature. In section 3 we introduce the basic model, in which the conditions for the production choice are derived. The welfare analysis of the production organization follows in section 4. Finally, we sum up the results in section 5.

2 Related literature

The literature deals with many different strands of outsourcing, because there are various types (vertical or horizontal) and different definitions (make-or-buy or fragmentation/input trade).[3] So, outsourcing has been discussed in depth. However the strategic aspects, i.e. the organizational choice as a result of competition pressure, have been ignored for a long time.

To our knowledge Nickerson und Vanden Bergh (1999) are the first who discuss the strategic implications of organizational choices. Within a duopoly, they derive the conditions for the production structure in the different Nash-Cournot-equilibria from the trade-off of fixed cost savings against higher marginal costs in the presence of outsourcing. Also Shy and

[3] Vertical outsourcing is characterized by the fact that an input producer is specialized in the intermediate good production. In contrast, horizontal outsourcing describes the fact that firms compete in the output market, but a single firm also produces parts for a rival firm. In the case of the make-or-buy choice, transaction costs, as well as non-completed contracts and their effects on a firm's choice are being considered as in Grossman and Helpmann (2003) and McLaren (2000). If outsourcing is interpreted as fragmentation, its effects with regard to trade models are discussed (see Jones, 2000, Jones and Kierzkowski, 2001 or Kohler, 2004).

Stenbacka (2003) analyze the behavior of firms concerning the organizational choices. However, they use a Hotelling model with differentiated goods. Here, also, the structure is determined by the trade-off of lower fixed costs and higher marginal costs in the case of outsourcing. Both studies conclude that in the case of relatively high (low) fixed costs and/or low (high) marginal cost differences, the firms will outsource (produce integrated). Thus, in the case of bilateral outsourcing (integration), the outsourcing disadvantage, i.e. higher marginal costs, will (not) be outweighed by the outsourcing advantage, i.e. the fixed cost saving. So, outsourcing (integration) is the dominating strategy, if for given fixed costs of the integrated production the difference of the marginal costs is small (high) enough, which means that the outsourcing price is only a little bit (sufficiently) higher than the integrated marginal production costs. Therefore, if the difference of marginal costs increases, the incentive to outsource the input production decreases. In the case of a medium fixed cost level and/or a medium marginal cost difference, the market constellation is characterized by different production structures.

The strategic interactions of firms concerning the production choice are also shown by Eberfeld (2001). Assuming the same trade-off, it is shown that firms in the same industry can chose different production structures. The reason is that with an integrated production, due to lower marginal costs, the firm reduces its price and creates an externality for the rival firm. So, the rival firm can avoid the competition pressure by choosing outsourcing. Since the integrated production has higher investment cost it becomes more difficult to bear these costs with a decreasing market price by choosing also an integrated production structure.

In contrast to these studies, Buehler and Haucap (2006) assume in their duopoly a sequential decision process. So the first mover firm is a Stackelberg-leader concerning the production structure. Also the external procurement price is not constant, and rises with more outsourcing. Since the firms face the above mentioned trade-off between lower fixed costs and higher variable costs by using outsourcing, the three constellations are: i) both firms use outsourcing, ii) both firms produce integrated or iii) different market structures subject to the cost relation.[4]

[4] The mentioned papers look on strategic effects of integration or separation of the input production for a final good producer. However, this question can also be considered as a decision for the input producer. This forward integration looks on the independence of an input firm. The

Also Shy and Stenbacka (2005) and König (2010) analyze the strategic aspect of outsourcing. In contrast to the above mentioned paper, where the firm can choose complete outsourcing or no outsourcing, they analyze the possibility of partial outsourcing. In that case, one unit of the final good is produced by a continuum of inputs. Additional, the motivation of outsourcing is reversed, i.e. the input supplier has lower marginal costs due to a higher specialization, but outsourcing requires higher fixed costs compared to the integrated production because of search frictions or monitoring. Both studies show in a Cournot-duopoly with homogenous goods and Nash-behavior concerning the production choice, that the numbers of outsourced inputs are strategic substitutes, i.e. more outsourcing of one firm leads to less outsourcing of the other firm. The reason is that the second firm can reduce the intensity of competition and avoid higher investments costs by producing more integrated. As presented in König (2010), this result does not depend on the cost trade-off and thus on the motivation of outsourcing. Bi-sourcing (make-and-buy) as another form of partial outsourcing and its strategic effects is analyzed in Du et al. (2006, 2009) as well as in Beladi and Mukherjee (2012). These studies show that the strategic effects of this type of production organization reduce the price for external procurement and minimize the hold-up problem between input supply and demand.[5]

While all these studies focus on the strategic aspect of outsourcing, in Spiegel (1993) and Arya et al. (2008) the welfare effects are analyzed. However, these are also examples for the case of horizontal outsourcing, where a firm outsources an input production to a competitor in its final good market. Spiegel (1993) demonstrates that with horizontal outsourcing, the production can be efficiently divided among the companies. Outsourcing increases the subcontractor's costs, who thus offer

strategic effects of the integration/separation-decision of an input producer in oligopolistic markets is analyzed by, e.g. Gal-Or (1990) and Jansen (2003), which are different in the assumption about the competition in the final good market and in the results they obtain. Gal-Or (1990) assumes a Bertrand-competition in the final market and found that all or no input producer are independent. Thus, there is, from the final good producer's point of view, no outsourcing or only outsourcing. Jansen (2003), however, assumes a Cournot-competition in the final good market and shows that integrated and separated input producer exist at the same time.

[5] The "hold-up"-problem describes the opportunistic behavior by the input producer, if special investments are needed, since the special requirements can't be easily written in a contract due to a too complex and unpredictable economic environment. In that case it can be impossible to design a contract that accounts for all outcomes and thus the contract becomes incomplete. In Spencer (2005) the relationship of incomplete contracts and outsourcing is presented.

less output in the final good market, whereas the other company has lower costs and offers a higher amount of output. However, the effect on the total output and the consumer price is ambiguous, so that when comparing the positive increase in efficiency with the effect on the consumer surplus, a clear welfare statement can only be derived in the case of a rising total output. Arya et al. (2008) compare the welfare in different equilibria under Bertrand- and Cournot-competition. Since the input producer can set a high price, the outsourcing firm is met with higher costs and loses some of its aggressiveness in a Bertrand-competition, which may result in a higher output price and consequently, less welfare than under Cournot-competition.[6]

In this paper we discuss the strategic effects and welfare implications of outsourcing in a duopoly with Cournot-competition. Thus, our model is in line with Nickerson and Vanden Bergh (1999) or Shy and Stenbacka (2003) but focuses additionally on the welfare aspects. Using the total surplus, i.e. the sum of consumer surplus and the profits, as the welfare indicator we are also orientated on Araya et al. (2008). However, we assume vertical outsourcing. Therefore, we can show the condition for the different equilibria and whether individual rational behavior concerning the production choice leads to collective rational behavior concerning the welfare level, i.e. is outsourcing as bad as it is seen.

3 Basic model

We assume that two identical firms – A and B – compete in the market. The competition equals a Cournot-duopoly in homogeneous goods, where the market demand is described by $p = a - b \cdot (y_A + y_B)$. The parameter y_i with $i = A; B$ characterizes the output of a firm, while p is the resulting price and a the maximum willingness-to-pay.

In both companies, the production of one unit of the output good requires one unit of an input component. The companies can choose between in-house production or outsourcing of the input component. The price for the external procurement of one input unit from abroad is fixed

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[6] Also the welfare effects of cross-supplies, where firms in an industry sell the final good to each other, is studied in the literature. Baake et al. (1999) show that cross-supplies always increase welfare compared to the standard Cournot-outcome.

and exogenously given by q. Alternatively, the component can be produced in-house (integrated) and requires an investment F, which is interpreted as set-up costs. The marginal costs m of the integrated production are constant too. Therefore, outsourcing is beneficial as investment costs F can be saved. To avoid external procurement being the dominant strategy, $q > m$ must hold.[7] Thus, if a domestic company chooses outsourcing, it pays a bonus to the external supplier for bearing the fixed costs. Consequently, the total costs of a company $i = A; B$ are

$$TC_i(y_i) = \begin{cases} m \cdot y_i + F & \text{for using in-house} \\ q \cdot y_i & \text{for using outsourcing.} \end{cases} \quad (1)$$

Equation (1) describes a situation, where a firm has the choice to build up a production capacity in its home plant, i.e. a firm invests and bears the fixed costs or buys the component from an external supplier and pays a mark-up compared to the marginal costs of the integrated production.

The structure of the model is:

(Ⅰ) Each company i $(i = A; B)$ chooses external procurement or in-house production, given the competitor's choice.

(Ⅱ) Given its own and the competitor's production structure, the company chooses its profit maximizing output.[8]

Thus, we have a two-stage decision problem, which is solved via backwards induction.

In the following analysis, the individual production structure is illustrated by the superscript indices *in* for in-house and *out* for outsourcing. So the constellation of production modes are characterized by in/in, if both firms choose integrated production or out/out, if both firms use outsourcing and in/out for different strategies.

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7 In our framework the firms face a trade-off between investment costs savings and additional marginal cost payments due to monitoring of the input quality. One example for this is the airbag in the automobile sector. Each car company can either produce the airbag in-house or buy it from outside the firm and thereby save the associated domestic fixed costs. Since the airbag technology is relatively similar in all types of cars, the airbag supplier can manufacture airbags for more than one firm, however the quality control leads to a higher outsourcing price per unit than the domestic marginal cost (here the quality is known and no additional payment occurs).

8 Thus, Nash-behavior is assumed regarding the outsourcing and output decision.

3.1 Stage II: Output decision

Notice, that we assume Nash-behavior, so that the output decision and the organizational choice of the competitor are given. Thus, the calculus of firm i is

$$\max_{y_i} \ \Pi^{in} = \left[p\left(y_i + y_j\right) - m\right] \cdot y_i - F \quad \text{or}$$
$$\max_{y_i} \ \Pi^{out} = \left[p\left(y_i + y_j\right) - q\right] \cdot y_i \tag{2}$$

with $i; j = A; B$ and $i \neq j$.

From (2) we can derive the individual reaction function for each constellation of the production structure. Solving the resulting equation system, we yield for each case the individual output.

Table 1. individual output

firm A \ firm B	outsourcing	in-house
outsourcing	$y^{out/out} = \frac{1}{3b}[a-q]$	$y_{in}^{in/out} = \frac{1}{3b}[a+q-2m]$ $y_{out}^{in/out} = \frac{1}{3b}[a+m-2q]$
in-house	$y_{in}^{in/out} = \frac{1}{3b}[a+q-2m]$ $y_{out}^{in/out} = \frac{1}{3b}[a+m-2q]$	$y^{in/in} = \frac{1}{3b}[a-m]$

To be sure that both participants stay in the market, the output levels have to be positive. Since the marginal outsourcing costs are higher than the domestic marginal costs, i.e. $q > m$, the condition for positive individual output for identical production strategies is $a > q$. When this requirement is fulfilled, the in-house producing participant in the case of different strategies will also offer a positive output level. However the outsourcing firm will offer a positive output if $a - q > q - m$.

Using the individual output levels, we can determine the total output and the market price.

Table 2. market output and market price

firm A \ firm B	outsourcing	in-house
outsourcing	$Y^{out/out} = \frac{2}{3b}[a-q]$ $p^{out/out} = \frac{1}{3}[a+2q]$	$Y^{in/out} = \frac{2}{3b}\left[a-\frac{q+m}{2}\right]$ $p^{in/out} = \frac{1}{3}[a+(q+m)]$
in-house	$Y^{in/out} = \frac{2}{3b}\left[a-\frac{q+m}{2}\right]$ $p^{in/out} = \frac{1}{3}[a+(q+m)]$	$Y^{in/in} = \frac{2}{3b}[a-m]$ $p^{in/in} = \frac{1}{3}[a+2m]$

As one can see, the resulting market price is positive in each constellation. However, we have to secure that $0 < p < a$ holds, since the parameter a represents the maximum willingness-to-pay. Comparing the different price levels with this requirement, it becomes clear that the market price under bilateral outsourcing is always below the maximum willingness-to-pay, i.e. $p^{out/out} < a$, if $a > q$. Since in our set-up we have $q > m$, it follows that $p^{in/in} < a$. In the case of different production structures, $p^{in/out} < a$ applies, given that $a > (q+m)/2$. This requirement is always met if $q > m$ and $a > q$.

To secure positive individual outputs and a market price below the maximum willingness to pay, we define

Assumption 1: For the following analysis we assume $a > q > m$ *and* $a - q > q - m$ *respectively* $q < (a+m)/2$.

From Table 2 we can also compare the prices in the different scenarios. As one can see, in the case of bilateral outsourcing the price is higher than the price in the case of bilateral integrated input production. The reason is that the external procurement price (the marginal cost of outsourcing) is higher than the domestic marginal costs, i.e. $q > m$. If different production structures characterize the market constellation, a medium price level is realized, since the price level depends on the average marginal production costs. Thus, we have $p^{out/out} > p^{in/out} > p^{in/in}$.

In the same way, the total output and the individual output can be compared. In the case of bilateral outsourcing, due to the higher output price and the downward sloping market demand, the total output is smaller compared to the case when both companies use in-house production. If both companies use the same strategies, the firms share the market in equal parts and thus individual output is lower in the case of bilateral outsourcing compared to the case of bilateral in-house production. Under different production structures, a medium price level is achieved, which also entails a medium total output level. However, the individual market shares differ due to the different marginal costs of the production structures. The market share of the outsourcing company is $s_{out}^{in/out} = \frac{y_{out}^{in/out}}{Y^{in/out}} = \frac{(a-q)-(q-m)}{(a-q)+(a-m)}$ and the share of the integrated producing firm is $s_{in}^{in/out} = \frac{y_{in}^{in/out}}{Y^{in/out}} = \frac{(a-m)+(q-m)}{(a-q)+(a-m)}$. Thus, the firm who uses in-house production has a larger market share and benefits from the marginal cost advantage. Since the market is divided up between the firms, in the case of different production strategies it follows that $s_{out}^{in/out} < \frac{1}{2} < s_{in}^{in/out}$. [9] For given production costs and organizational choices we can summarize our findings as follows

Proposition 1:

a) *For the prices,* $p^{out/out} > p^{in/out} > p^{in/in}$ *applies and resulting in* $Y^{in/in} > Y^{in/out} > Y^{out/out}$ *for the total output.*
b) *For the individual output, we have* $y_{in}^{in/out} > y^{in/in} > y^{out/out} > y_{out}^{in/out}$.

[9] When the external procurement price rises, the marginal cost difference increases in favor of the in-house producing company, which leads to an increase in its output and market share, while the output and market share of the outsourcing company decreases, i.e. $\partial s_{in}^{in/out} / \partial q > 0$ and $\partial s_{out}^{in/out} / \partial q < 0$.

3.2 Stage I: Outsourcing decision

Since the firms are interested in maximizing their profits, the profit determines the organizational structure. Using our former results, we can calculate the individual profits in the different scenarios.

Table 3. profits

firm A \ firm B	outsourcing	in-house
outsourcing	$\Pi^{out/out}=\frac{1}{9b}(a-q)^2$	$\Pi^{in/out}_{in}=\frac{1}{9b}(a+q-2m)^2-F$ $\Pi^{in/out}_{out}=\frac{1}{9b}(a+m-2q)^2$
in-house	$\Pi^{in/out}_{in}=\frac{1}{9b}(a+q-2m)^2-F$ $\Pi^{in/out}_{out}=\frac{1}{9b}(a+m-2q)^2$	$\Pi^{in/in}=\frac{1}{9b}(a-m)^2-F$

In an equilibrium with bilateral outsourcing both firms realize positive profits if $a>q$. In the case of different strategies, $a-q>q-m$, is sufficient to provide the outsourcing firm with a positive profit. For the in-house producing company $[(a-m)+(q-m)]^2>9bF$ must apply. In a market constellation where both companies produce integrated, $(a-m)^2>9bF$ has to be fulfilled. Since we assume that $q>m$, the essential and binding condition is $(a-m)^2>9bF$. Thus, in addition to Assumption 1, we have a second assumption, which ensure positive profits.

Assumption 2: In addition to Assumption 1, $(a-m)^2>9bF$ *applies.*

Using the profit levels, we can determine the critical values of the outsourcing price for the different market equilibria.[10] Both firms choose outsourcing if

$$q<q^{out/out}_{crit}=\frac{9b}{4}\frac{F}{(a-m)}+m \tag{3}$$

[10] Due to symmetry, the derived conditions apply to both participants. For details see Appendix A.

and if

$$q > q_{crit}^{in/in} = \frac{(a+m)}{2} - \sqrt{\frac{(a-m)^2}{4} - \frac{9b}{4}F} \tag{4}$$

both firms produce integrated.[11] Thus, a constellation with different production modes is characterized by

$$q_{crit}^{out/out} < q < q_{crit}^{in/in}. \tag{5}$$

It is intuitive, that for given fixed costs, the disadvantage of the integrated production, a relative low marginal cost mark-up, the disadvantage of disintegrated production, favors outsourcing. If the marginal costs are equal, i.e. there is no mark-up, outsourcing is the dominant production structure for both firms. Up to $q_{crit}^{out/out}$ the fixed costs saving due to outsourcing is more significant than the higher marginal costs.

If the external supplier bonus, i.e. the difference between in-house marginal costs and outsourcing price, is sufficiently high so that the fixed cost savings achieved through outsourcing cannot compensate the higher marginal costs, both participants will choose in-house production.

Also an equilibrium in different strategies can be explained in an intuitive way. If firm B uses outsourcing, firm A will choose the integrated production only if for given fixed costs the integrated marginal costs are sufficiently low, i.e. the marginal costs mark-up (the outsourcing disadvantage) is sufficiently big. Only in that case, the market share of firm A is high enough to bear the fixed costs of the integrated production. In contrast, if firm B chooses the integrated production, firm A chooses outsourcing if the mark-up is sufficiently high. The reason is that via outsourcing firm A can dampen the competition pressure. If firm A would choose the integrated production too, the resulting market price is too low for bearing the associated fixed costs of the integrated production.

[11] In a Nash-equilibrium where both firms produce integrated, we obtain two solutions due to the quadratic structure. However, the critical value has to fulfill Assumption 1. Thus, he has to lie in the interval $(m;a)$ and has to be smaller than $(a+m)/2$. See Appendix A.

4 Production choice and welfare

We know the effects of the production structure on the firm's profit, i.e. on the supply side. However, the production choice also affects the consumer side via the price. To evaluate the implications of the production structure on the overall economy, we use the welfare criterion.

Here, we compare the welfare under the different market constellations. So we derive conditions to show which production structure will be superior or inferior to another. These threshold values can be compared with the critical values from section 3 to answer if rational behavior by the firms is the best behavior from a welfare point of view, i.e. is outsourcing as bad as it is seen.

The welfare indicator used here, consists of the sum of the rents, i.e. the profits and the consumer rent. Using the known results, we obtain (see Appendix B)

Table 4. welfare

	welfare
both use outsourcing	$W^{out/out} = \frac{4}{9b}[a-q]^2$
both use different strategies	$W^{in/out} = \frac{1}{9b}\left[4(a-m)(a-q)+\frac{11}{2}(q-m)^2\right]-F$
both use in-house	$W^{in/in} = \frac{4}{9b}[a-m]^2 - 2F$

Both firms use outsourcing

From Table 4, we can derive the iso-welfare line $W^{out/out} = W^{in/out}$ and receive the relationship between fixed costs and outsourcing price, where there is an equal welfare level in different production modes and bilateral outsourcing. The resulting critical outsourcing price is[12]

[12] Solving the underlying quadratic equation, we yield two critical values, however the second does not match our assumptions and therefore can be neglected. See Appendix C.

$$\hat{q} = -\frac{4a-7m}{3} + \sqrt{\frac{16}{9}(a-m)^2 + 6bF} \; . \tag{6}$$

An increase of the outsourcing price for given fixed costs favors the integrated production, so that for $\hat{q} < q$ welfare will be higher in a constellation with different production modes than in a constellation where both firms outsource the input production. Since for $q < q_{crit}^{out/out}$ both firms use outsourcing it follows that for $\hat{q} < q < q_{crit}^{out/out}$ welfare increases if one firm doesn't follow her rational choice and use outsourcing, but produce with an integrated production mode.

Therefore, to answer, if a change from the optimal choice of bilateral outsourcing towards a constellation with different strategies increases welfare, we have to compare the equations (3) and (6). Here, we find that (see Appendix D)

$$m < \hat{q} < q_{crit}^{out/out} \; .$$

Thus, welfare increases, if one firm doesn't behave rationally and now uses integrated input production. The marginal costs of the firm that changes its strategy to integrated production decrease, thereby reducing the average marginal costs in the market and the market price. These effects will be accompanied by a rise in the total output. Since lower market price and higher output favor the consumer, the consumer surplus increases. In contrast, both companies suffer profit losses: the company that continued by using outsourcing as the output price falls at constant marginal costs and the company with integrated production, as it acts against its best strategy. However, in the interval $(\hat{q}; q_{crit}^{out/out})$ the marginal cost difference is sufficiently high, so that the positive effect on the consumer surplus caused by a relatively large price reduction prevails and the welfare will be higher with different production structures. If the outsourcing price is sufficiently low and lies in the interval $(m; \hat{q})$, there is only a relative small marginal cost difference and the negative effect on profits prevails, so that the welfare level in an asymmetrical production structure is smaller.

This result shows, that from a welfare point of view outsourcing can be as bad as it is seen and the government should intervene to avoid the case that both/all firms use outsourcing.

In a similar way, we can analyze, whether a constellation where both firms produce in an integrated way is superior or inferior compared to a situation where both firms use outsourcing. From the iso-welfare line $W^{out/out} = W^{in/in}$, we yield[13]

$$\tilde{q} = a - \sqrt{(a-m)^2 - \frac{9b}{2}F} \tag{7}$$

where the welfare level in both constellations is equal. If the fixed costs of the integrated production are given and the outsourcing price rises, outsourcing becomes less attractive. Thus, for $\tilde{q} < q < q_{crit}^{out/out}$ welfare increases if both firms produce in an integrated production mode and don't use outsourcing, i.e. their rational choice. Comparing this threshold value with the upper bound of using outsourcing, i.e. $q_{crit}^{out/out}$, shows that (see Appendix D)

$$m < q_{crit}^{out/out} < \tilde{q} .$$

From this finding follows, that in a Nash-equilibrium with bilateral outsourcing, i.e. $q < q_{crit}^{out/out}$, welfare cannot increase when both participants don't behave rationally and switch from outsourcing to in-house production. Changing the production mode, both firms act against their best strategies and thus their profits decrease as the fixed costs are not compensated by the lower marginal costs. On the other side, there is an increase in the consumer surplus due to the lower marginal costs and resulting lower market price. However, due to a too small difference between outsourcing costs and marginal costs of integrated production, this positive effect is not strong enough to compensate the firms' losses. Thus, changing the production structure from bilateral outsourcing to bilateral in-house production leads to lower welfare.

[13] Also here, we have to solve a quadratic equation. However the second solution does not fulfill our assumptions. For more details see Appendix C.

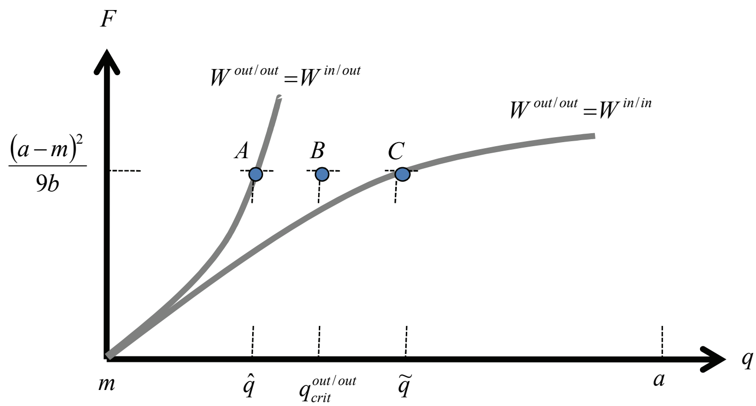
Therefore, we can sum up in:

Proposition 2:
If the market constellation is characterized by bilateral outsourcing,

a) *this constellation is superior to a constellation with bilateral in-house production,*
b) *this constellation is superior to a constellation with different production modes, if the outsourcing price is sufficiently low,* $q < \hat{q} < q_{crit}^{out/out}$,
c) *this constellation is inferior to a constellation with different production modes, if the outsourcing price is sufficiently high,* $\hat{q} < q < q_{crit}^{out/out}$.

Our findings are illustrated in Figure 1.

Figure 1. welfare if both firms use outsourcing



In point A the welfare level in a constellation with different production modes is equal to the welfare level in a constellation where both firms use outsourcing. If for a constant outsourcing price and integrated marginal costs the fixed costs decrease, the welfare level in a constellation where both firms use outsourcing is unchanged, while the welfare level in a constellation with different production modes increases (more profits). Thus, for all combinations under the

$W^{out/out} = W^{in/out}$ -line we have $W^{out/out} < W^{in/out}$. So, for all outsourcing prices between A and B welfare increases, if one firm doesn't behave rationally, i.e. a constellation where both firms use outsourcing is inferior to a constellation with different production modes. But left from A, i.e. in the interval $(m;\hat{q})$, we are above the $W^{out/out} = W^{in/out}$ -line so that here a constellation where both firms use outsourcing is superior to a situation with asymmetric production modes.

Similarly, we can compare a constellation where both firms use outsourcing and a constellation where both firms produce integrated. In point C the welfare levels in both production modes are equal. If for a constant outsourcing price and integrated marginal costs the fixed costs decrease, the welfare level in a constellation where both firms use outsourcing is unchanged, while the welfare level in a constellation where both firms produce integrated increases (more profits). Thus, for all combinations over the $W^{out/out} = W^{in/in}$ -line we have $W^{out/out} > W^{in/in}$. Since $q_{crit}^{out/out} < \tilde{q}$, for all outsourcing prices between B and C, welfare decreases if both firms don't behave rationally. Thus, a constellation where both firms use outsourcing, i.e. $q < q_{crit}^{out/out}$, is superior to a constellation where both firms produce integrated.

Both firms use in-house production

From the paragraph above, we know that welfare wouldn't increase if both firms behave rationally and use outsourcing but then change their production strategies towards an integrated production. But is this also true for the opposite, i.e. if rational behavior leads to a constellation where both firms use in-house production, will welfare increase if both firms didn't behave rationally? It is intuitive that welfare can only increase, if the increase in consumer surplus outweighs the loss of profits, since both firms act against their best strategies. However, an increase in consumer surplus can only be achieved with higher output and/or lower price. But changing the production mode towards outsourcing increases the average marginal production costs and therefore the market price, while the output decreases. Thus, all parties suffer losses and the welfare wouldn't increase.

Using our former results, we know that $W^{out/out} = W^{in/in}$ is characterized by $\tilde{q}$. If the costs of the integrated production are given and the outsourcing price falls, outsourcing becomes more attractive. Thus, for

$q < \tilde{q}$ we have $W^{out/out} > W^{in/in}$. So, starting from a structure where both firms produce in-house and both firms don't behave rationally, the welfare level increases if $q_{crit}^{in/in} < q < \tilde{q}$. Comparing $\tilde{q}$ with $q_{crit}^{in/in}$ we find that (see Appendix D)

$$\tilde{q} < q_{crit}^{in/in} .$$

Since both firms chose the integrated production if $q > q_{crit}^{in/in}$, it follows that welfare decreases, if both firms don't behave rationally and change their production structure towards outsourcing. As argued above, this result is intuitive and not surprising.

What happens if only one firm doesn't behave rationally and changes its production structure towards outsourcing? Since the average marginal costs and thus the output price increase while the amount of output decreases, the consumer surplus falls. On the other side the firm, who changed its production strategy loses profit but the still integrated producing firm increases its profit. The reason is that the first firm acts against its best strategy and the second firm realizes a higher market share which corresponds with higher revenue per output unit at constant marginal costs. So, the effect on the welfare level is ambiguous. To get a clear answer, we compare the outsourcing price, where there is an equal welfare level in a constellation where both firms use in-house production and in a constellation with different production modes with the critical value of the outsourcing price where it becomes rational for both firms to choose integrated production, i.e. $q_{crit}^{in/in}$. From the iso-welfare line $W^{in/in} = W^{in/out}$, we yield the threshold values

$$\bar{q}_{1;2} = \frac{4a+7m}{11} \pm \sqrt{\frac{16}{121}(a-m)^2 - \frac{18}{11}bF} \tag{8}$$

For given fixed costs in a situation where the welfare levels are equal, a fall or a rise of the outsourcing price doesn't affect the welfare in a constellation where both firms use in-house production, but affects the welfare level in a constellation with different production modes. So, above this iso-welfare line, the welfare in a constellation where both firms use different production modes is higher than in a constellation where both firms use in-house production.

From the specific form of the $W^{in/in} = W^{in/out}$-curve, we can see that for $q_{crit}^{in/in} < q < \overline{q}_1$ and $q_{crit}^{in/in} < \overline{q}_2 < q$ welfare increases if one firm uses outsourcing and doesn't behave rationally (due to the quadratic structure of equation (8), see also Figure 2).

However, equation (8) has to meet our Assumption 1 and 2 too. It is easy to see, that we have to adopt Assumption 2. Therefore we can distinguish two cases.

$$\textit{Case I:}\ (a-m)^2 > 9bF > \frac{8}{11}(a-m)^2$$

The iso-welfare line $W^{in/in} = W^{in/out}$ has its maxima at $9bF = \frac{8}{11}(a-m)^2$. Since for $9bF > \frac{8}{11}(a-m)^2$ we are above the $W^{in/in} = W^{in/out}$-curve there is no solution for equation (8). Here, a constellation with different production structures yields a higher welfare level than a structure where both firms produce integrated. Starting in a constellation with bilateral integrated production, i.e. $q_{crit}^{in/in} < q$, and sufficiently high fixed costs, i.e. $9bF > \frac{8}{11}(a-m)^2$, a change towards different strategies leads to a rise in the average marginal costs of production and, consequently, the market price. At the same time, output and consumer surplus are lower. This is met by an increase in the producer rent. Although the outsourcing company now suffers a profit loss, since its market share falls below 50%, the profit gain of the company that keeps on producing integrated is sufficiently high, so that there is not only a rise in the producer rent, but in welfare as well.

$$\textit{Case II:}\ \frac{8}{11}(a-m)^2 > 9bF$$

Only under this condition, we receive a solution for equation (8). However, we have to ensure that Assumption 1 is also met, i.e. $\overline{q}_{1;2} \in (m\,;a)$. Comparing both solutions from (8) with the parameter m and a, we find that $m < \overline{q}_{1;2} < a$ (see Appendix C).

To answer, if it is preferable that one firm doesn't behave rationally, although both firms will optimally decide on an integrated production, we have to analyze whether $q_{crit}^{in/in} < q < \overline{q}_1$ and $q_{crit}^{in/in} < \overline{q}_2 < q$ is fulfilled.

Comparing these threshold values, we found that (see Appendix D)

$$q_{crit}^{in/in} < \overline{q}_1 < \overline{q}_2 .$$

So, although the firms behave optimally and choose a constellation with bilateral integrated production, the welfare in different strategies can be higher. Thus, a change towards different strategies would increases welfare. As mentioned above, using outsourcing reduces the profit of the firm that acts against its best strategy. Also the consumer surplus is lower, due to a higher market price (higher average marginal costs) and less output. However, the positive profit effect of the still in-house producing participant outweighs these negative effects.

We can summarize as follows:

Proposition 3:

If the market constellation is characterized by bilateral in-house production,

a) this constellation is superior to a constellation with bilateral outsourcing,

b) this constellation is inferior to a constellation with asymmetric production modes if the fixed costs are sufficiently high, i.e. $(a-m)^2 > 9bF > \frac{8}{11}(a-m)^2$,

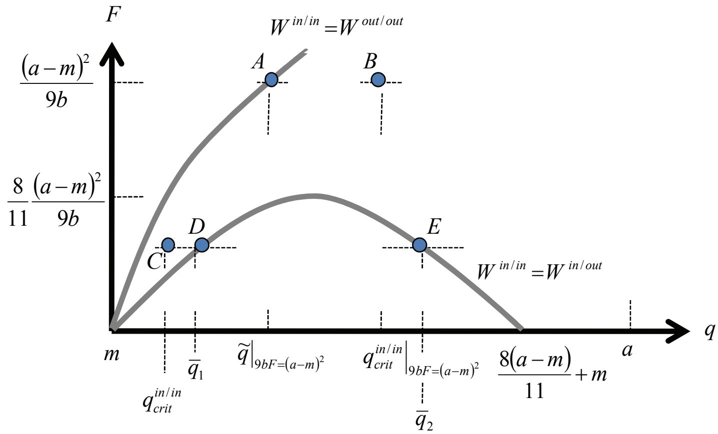
c) this constellation is inferior to a constellation with asymmetric production modes for $q_{crit}^{in/in} < q < \overline{q}_1$ *or* $\overline{q}_2 < q < a$ *if the fixed costs are sufficiently low, i.e.* $\frac{8}{11}(a-m)^2 > 9bF$,

d) this constellation is superior to a constellation with asymmetric production modes for $q_{crit}^{in/in} < \overline{q}_1 < q < \overline{q}_2$ *if the fixed costs are sufficiently low, i.e.* $\frac{8}{11}(a-m)^2 > 9bF$.

Similar to the paragraph above, our findings are graphically illustrated in

Figure 2.

Figure 2. welfare if both firms use in-house production



In point A the welfare level in a constellation where both firms use in-house production is equal to the welfare level in a constellation where both firms use outsourcing. If for a constant outsourcing price and integrated marginal costs the fixed costs decrease, the welfare level in a constellation where both firms use outsourcing is unchanged, while the welfare level in a constellation where both firms use in-house production increases (more profits). Thus, for all combinations under the $W^{in/in} = W^{out/out}$ -line we have $W^{in/in} > W^{out/out}$. Since both firms use in-house production for all $q_{crit}^{in/in} < q$ but $\tilde{q} < q_{crit}^{in/in}$, between B to A the welfare level decreases if both firms don't behave rationally, i.e. a constellation where both firms use in-house production is superior to a constellation where both companies use outsourcing.

Similarly, we can compare a constellation where both firms use in-house production with a constellation of different production modes. In point D and E the welfare levels in both production modes are equal. If for a constant outsourcing price and integrated marginal costs the fixed costs decrease, the welfare level in a constellation where both firms use in-house production increases as well as in a constellation with different production structures. However, in a case of integrated production we gain twice the lower fixed costs. Thus, for all combinations below the

$W^{in/in} = W^{in/out}$-line we have $W^{in/in} > W^{in/out}$. Since both firms choose integrated production for $q_{crit}^{in/in} < q$ but also $q_{crit}^{in/in} < \bar{q}_1$ holds, between C and D there is space for a welfare increasing change of the production mode, i.e. between these points welfare increases if one firm doesn't behave rationally. This also holds for $\bar{q}_2 < q$, i.e. right from point E. Thus, a constellation where both firms use in-house production can be superior but also inferior to a constellation with different production modes.

Different strategies characterize the market constellation

In our previous analysis, we already looked in part at the constellation with different strategies, which is given for $q_{crit}^{out/out} < q < q_{crit}^{in/in}$.

We know that for $q < \hat{q}$ the welfare when both firms use outsourcing is higher than with different production modes. However, we also know that $\hat{q} < q_{crit}^{out/out}$ applies. So, starting with an asymmetric production mode, a transition to bilateral outsourcing wouldn't increase the welfare. The explanation is intuitive. The deviation of the in-house producing participant increases the average marginal costs and thus, the output price, which results in a reduction in the output and, consequently in a lower consumer surplus. Since the firm acts against its best response strategy, its profit and market share decline. On the other hand, the outsourcing participant gets a higher market share and increases its profits by increasing the output. This effect however does not compensate other market participants' loss. Thus, welfare would be lower with bilateral outsourcing compared to a constellation with different strategies.

Similarly, when the outsourcing company switches to in-house production, it acts against its best response strategy and loses profit. In addition, the still in-house producing company loses profits, as its market share falls. In contrast, the consumer surplus increases due to lower marginal costs and thus a lower market price. However, the positive effect is not sufficient to compensate the negative effects. Thus, welfare decreases. Formally, this is documented for any fixed costs by $q_{crit}^{in/in} < \bar{q}_{1;2}$.

Therefore, we have

Proposition 4:
A market constellation characterized by asymmetric production strategies is always superior to a constellation with symmetric production modes.

The previous analysis allows a simple and clear conclusion. If in a market of independent companies, some firms choose to procure their input externally while other firms produce their required input integrated, the companies act optimally and also for the benefit of a welfare oriented institution. The reason is that, based on an equilibrium with unchanged costs, welfare cannot increase by a potential change of the production structure.

On the other hand, in the case of symmetric production structures, despite the companies' profit orientation, at given costs a potential change towards an asymmetric production organization may be accompanied by a gain in welfare. This may provide some leeway for market interferences to increase the welfare level by influencing operational decisions concerning the production structure.

However, given the in-house production costs m and F, this is only true for some certain values of the outsourcing price q. So governmental interactions are only justified in case of

i) a constellation where both firms outsource the input production if $\hat{q} < q < q_{crit}^{out/out}$,

ii) a constellation where both firms use an integrated input production mode if $(a-m)^2 > 9bF > \frac{8}{11}(a-m)^2$,

iii) a constellation where both firms use an integrated input production mode if $q_{crit}^{in/in} < q < \overline{q}_1$ or $q_{crit}^{in/in} < \overline{q}_2 < q$ for $\frac{8}{11}(a-m)^2 > 9bF$.

Finally we can conclude: outsourcing is not in any case as bad as it is seen and some governmental interactions towards outsourcing can increase the overall welfare.

5 Concluding remarks

The paper's aim was to demonstrate the strategic interactions of production organizations and their welfare implications in a duopoly with homogeneous goods. Outsourcing was interpreted as a long-term investment decision whereby fixed costs could be saved. On the other hand, the marginal costs of external procurement are higher than the marginal costs of in-house production. Consequently, the trade-off between fixed cost savings and a rise in marginal costs determines the company's production choice. Since the cost structure of a firm determines its market position but also affects the position of the rival firm, the choice of the production organization has a strategic component. Given the different cost parameters, the resulting strategic interactions characterize the market equilibrium. Here we find for given fixed costs, that for a relatively small marginal cost difference, outsourcing becomes the dominant strategy, whereas at a sufficiently high marginal cost difference, both companies will choose in-house production. In the case of a medium marginal cost difference, there are different production structures.

Via the marginal costs, the choice of the production mode affects the output price and the consumer. Since both sides of the market, i.e. producer and consumer, are affected, we analyze the implications of the production choice from the welfare point of view. Here, we find that if the firms' profit orientation leads to symmetric production modes a potential change of the production structure by both firms never increases the welfare level. The comparison of the welfare levels of a market structure with symmetric production modes and the constellation of different modes revealed that the optimally chosen production strategy is not always superior. Here, we find that for a number of sufficiently big (small) marginal cost disadvantages of external procurement, welfare would be higher in different strategies than in the dominant strategy of bilateral outsourcing (bilateral in-house production). This means that for a constellation with bilateral outsourcing, the negative effect on the firm's profits will be offset by the increase of consumer surplus, while in the case of a constellation with bilateral in-house production, the profit increase of the still integrated producing firm will compensate the profit loss of the outsourcing firm and the decrease of consumer surplus. Additionally, in the case of a constellation with different production structures, we showed that the companies' profit orientation ensures superiority from a welfare point of view.

Notice, that we assume profit maximizing behavior for the firms. Thus, there are no incentives for the firms to change their decisions. However, given the decisions of the firms, our aim is to analyze, whether profit orientation by the firms leads to superior situations and whether there is scope for interactions of a welfare interested government by setting incentives for changing the production mode. From our analysis, we thus come to the conclusion that in the case of symmetric production strategies, market interference affecting the companies' production choice may be required in order to increase welfare, while interferences affecting the companies' production choice decrease the welfare in the case of different production modes. So, there is in general no reason to avoid outsourcing since it is not always as bad as it is seen.

Note, that the analysis shows only whether outsourcing lowers the welfare level or not and thus if there is scope for governmental interactions. It is shown that for certain circumstances policy interactions increase the overall welfare level and therefore in those cases these interactions are justified.

Due to the assumed profit orientation some subsidies for the firms are needed to compensate the profit loss, since to increase the welfare level, the firms have to act against their optimal strategy. However, we don't answer which is the best governmental interaction. Therefore, the analysis can only be a first step to derive policy implications. So further research is needed, which should focus on partial outsourcing, different subsidies or taxes and an imperfect input market and the resulting welfare implications.

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Appendices

Appendix A: Nash-Equilibria of the Production Choices

For the Nash-equilibria, the profits of a firm in the different scenarios have to be compared. So, if firm A (B) chooses outsourcing, firm B (A) chooses outsourcing if $\Pi^{out/out} > \Pi_{in}^{in/out}$ or in-house production if $\Pi_{in}^{in/out} > \Pi^{out/out}$. However, if firm A (B) chooses in-house production, firm B (A) chooses outsourcing if $\Pi_{out}^{in/out} > \Pi^{in/in}$ or in-house production if $\Pi^{in/in} > \Pi_{out}^{in/out}$. Thus, we can solve the conditions for the different market-equilibria.

a) bilateral outsourcing as a Nash-equilibrium

Both firms use outsourcing if $\Pi^{out/out} > \Pi_{in}^{in/out}$. Using the profits from Table 3 we can rewrite this condition as $\frac{1}{9b}[a-q]^2 > \frac{1}{9b}[a+q-2m]^2 - F$. Simplifying this expression, we obtain $F > \frac{4}{9b}(q-m)(a-m)$. Therefore, both firms choose outsourcing for

$$q < q_{crit}^{out/out} = \frac{9b}{4}\frac{F}{(a-m)} + m \tag{A.1}$$

b) bilateral in-house production as a Nash-equilibrium

Both firms choose in-house if $\Pi^{in/in} > \Pi_{out}^{in/out}$. Using the profits from Table 3 we can rewrite this condition as $\frac{1}{9b}[a-m]^2 - F > \frac{1}{9b}[a+m-2q]^2$ respectively $\frac{4}{9b}(a-q)\cdot(q-m) > F$. Solving this quadratic expression, we obtain $q_1 = \frac{a+m}{2} - \sqrt{\frac{(a-m)^2}{4} - \frac{9b}{4}F}$ and $q_2 = \frac{a+m}{2} + \sqrt{\frac{(a-m)^2}{4} - \frac{9b}{4}F}$. However, under the Assumptions 1 and 2, only q_1 is a solution. Therefore, both firms choose in-house production only for

$$q > q_{crit}^{in/in} = \frac{a+m}{2} - \sqrt{\frac{(a-m)^2}{4} - \frac{9b}{4}F} \tag{A.2}$$

c) Nash-equilibrium in different strategies

An equilibrium in different production choices is characterized by $\Pi_{in}^{in/out} > \Pi^{out/out}$ or $\Pi_{out}^{in/out} > \Pi^{in/in}$. Thus, we can use (A.1) and (A.2) for deriving the condition of a Nash-equilibrium in different strategies, which occur if

$$q_{crit}^{out/out} < q < q_{crit}^{in/in} \tag{A.3}$$

Appendix B: Consumer-Surplus and Welfare

The consumer surplus is the sum of the difference between the market price and the willingness to pay. Since we use a linear demand, graphically the consumer surplus is characterized by a triangle. Thus, we can use the formula for the superficial content of this triangle, i.e. $CS = Y \cdot (a-p)/2$.

Using this knowledge and the derived profit levels from Table 3, the welfare level in the different production structures as presented in Table 4 are:

$$W^{out/out} = CS^{out/out} + 2 \cdot \Pi^{out/out} = Y^{out/out} \cdot \left(a - p^{out/out}\right)/2 + 2 \cdot \Pi^{out/out}$$
$$W^{out/out} = \frac{4}{9b}[a-q]^2 \tag{B.1}$$

$$W^{in/in} = CS^{in/in} + 2 \cdot \Pi^{in/in} = Y^{in/in} \cdot \left(a - p^{in/in}\right)/2 + 2 \cdot \Pi^{in/in}$$
$$W^{in/in} = \frac{4}{9b}[a-m]^2 - 2F \tag{B.2}$$

$$W^{in/out} = CS^{in/out} + \Pi_{in}^{in/out} + \Pi_{out}^{in/out} = Y^{in/out} \cdot \left(a - p^{in/out}\right)/2 + \Pi_{in}^{in/out} + \Pi_{out}^{in/out}$$
$$W^{in/out} = \frac{1}{9b}\left[4(a-m)(a-q) + \frac{11}{2}(q-m)^2\right] - F \tag{B.3}$$

Appendix C: Comparison of the Welfare Levels

Similar to Appendix A, we can also compare the welfare levels to receive the critical values of the outsourcing price where a certain market structure is superior to another market constellation. So we have to solve the equations $W^{out/out} = W^{in/out}$, $W^{out/out} = W^{in/in}$ and $W^{in/in} = W^{in/out}$.

Rewriting $W^{out/out} = W^{in/out}$ we receive a quadratic condition. Solving this expression we obtain two solutions

$$\hat{q}_{1;2} = -\frac{4a-7m}{3} \pm \sqrt{\frac{16}{9}(a-m)^2 + 6bF}\,. \tag{C.1}$$

Using the same procedure we obtain as the solution of $W^{out/out} = W^{in/in}$ and $W^{in/in} = W^{in/out}$

$$\tilde{q}_{1;2} = a \pm \sqrt{(a-m)^2 - \frac{9b}{2}F} \quad \text{and} \tag{C.2}$$

$$\bar{q}_{1;2} = \frac{4a+7m}{11} \pm \sqrt{\frac{16}{121}(a-m)^2 - \frac{18}{11}bF}\,. \tag{C.3}$$

However, all these critical outsourcing prices have to fulfill the Assumptions 1 and 2.

For equation (C.1) it is easy to see, that the second term is positive. However (C.1) has to fulfill Assumption 1, i.e. $a > \hat{q}_{1;2} > m$. From $m < \hat{q}_2 = -\frac{4a-7m}{3} - \sqrt{\frac{16}{9}(a-m)^2 + 6bF}$ we have $-\frac{4}{3}(a-m) > \sqrt{\frac{16}{9}(a-m)^2 + 6bF}$. Since this is not true, $\hat{q}_2$ cannot be a critical value. From $m < \hat{q}_1 = -\frac{4a-7m}{3} + \sqrt{\frac{16}{9}(a-m)^2 + 6bF}$ we have $\frac{4}{3}(a-m) < \sqrt{\frac{16}{9}(a-m)^2 + 6bF}$. Rewriting this expression we obtain $6bF > 0$. Since this is true, $m < \hat{q}_1$ holds. But $a > \hat{q}_1$ has to be fulfilled too. Here we find that this is true for $\frac{7}{3}(a-m) > \sqrt{\frac{16}{9}(a-m)^2 + 6bF}$ respectively $(a-m)^2 > \frac{2}{11} \cdot 9bF$. Since this holds under Assumption 2, $\hat{q} = -\frac{4a-7m}{3} + \sqrt{\frac{16}{9}(a-m)^2 + 6bF}$ is the critical value presented in equation (6).

From (C.2) one can see that under Assumption 2 the second term is always positive. However, this means that $\tilde{q}_2 = a + \sqrt{(a-m)^2 - \frac{9b}{2}F}$ does not fulfill $a > \tilde{q}_2$, our Assumption 1. So we can concentrate on $\tilde{q}_1 = a - \sqrt{(a-m)^2 - \frac{9b}{2}F}$. Under Assumption 2 the second term is positive and therefore we have $a > \tilde{q}_1$. However, $m < \tilde{q}_1$ has also to be fulfilled. Solving $m < a - \sqrt{(a-m)^2 - \frac{9b}{2}F}$ we yield $0 > -\frac{9b}{2}F$. Since this is true, $\tilde{q} = a - \sqrt{(a-m)^2 - \frac{9b}{2}F}$ is the critical value presented in equation (7).

Using $\bar{q}_{1;2} = \frac{4a+7m}{11} \pm \sqrt{\frac{16}{121}(a-m)^2 - \frac{18}{11}bF}$, it is easy to see, that our Assumption 2 is not always met. So we distinguish two cases. For $(a-m)^2 > 9bF > \frac{8}{11}(a-m)^2$ the second term is negative and there is no solution for $W^{in/in} = W^{in/out}$. So we have to rewrite our Assumption 2 as $\frac{8}{11}(a-m)^2 > 9bF$. Simplifying $m < \bar{q}_1 = \frac{4a+7m}{11} - \sqrt{\frac{16}{121}(a-m)^2 - \frac{18}{11}bF}$ and $a > \bar{q}_1 = \frac{4a+7m}{11} - \sqrt{\frac{16}{121}(a-m)^2 - \frac{18}{11}bF}$, we find that $a > \bar{q}_1 > m$ holds under the reformulated Assumption 2. Solving $m < \bar{q}_2 = \frac{4a+7m}{11} + \sqrt{\frac{16}{121}(a-m)^2 - \frac{18}{11}bF}$ and $a > \bar{q}_2 = \frac{4a+7m}{11} + \sqrt{\frac{16}{121}(a-m)^2 - \frac{18}{11}bF}$, we found that this is also true under the reformulated Assumption 2. So we have $a > \bar{q}_{1;2} > m$.

Appendix D: Critical Values vs. Threshold Values

Comparing these values shows whether the resulting production constellation based on the individual rational choices is welfare superior or inferior to another production constellation.

Case A: both firms use outsourcing

In that case we have to compare equation (3) with equation (6) and (7).

From $q_{crit}^{out/out} = \frac{9b}{4}\frac{F}{(a-m)} + m > -\frac{4a-7m}{3} + \sqrt{\frac{16}{9}(a-m)^2 + 6bF} = \hat{q}$ we have $\frac{9b}{4}\frac{F}{(a-m)} + \frac{4}{3}(a-m) > \sqrt{\frac{16}{9}(a-m)^2 + 6bF}$, which can be simplified to $\left(\frac{9b}{4}\frac{F}{(a-m)}\right)^2 > 0$. Since this is true, $q_{crit}^{out/out} > \hat{q}$ holds.

In a similar way $q_{crit}^{out/out} = \frac{9b}{4}\frac{F}{(a-m)} + m < a - \sqrt{(a-m)^2 - \frac{9b}{2}F} = \tilde{q}$ can be simplified to $\left(\frac{9b}{4}\frac{F}{(a-m)}\right)^2 > 0$. Since this is true, we have $q_{crit}^{out/out} < \tilde{q}$.

Case B: both firms use in-house production

Here we compare equation (4) with equation (7) and (8).

Simplifying $q_{crit}^{in/in} = \frac{a+m}{2} - \sqrt{\frac{(a-m)^2}{4} - \frac{9b}{4}F} > a - \sqrt{(a-m)^2 - \frac{9b}{2}F} = \tilde{q}$ we obtain after some steps $\left(\frac{9b}{4}\frac{F}{(a-m)}\right)^2 > 0$. Since this is true, we have $q_{crit}^{in/in} > \tilde{q}$.

Comparing (4) with (8), we can concentrate on the relation $q_{crit}^{in/in} < \bar{q}_1$, since $\bar{q}_1 < \bar{q}_2$. Rewriting $q_{crit}^{in/in} = \frac{a+m}{2} - \sqrt{\frac{(a-m)^2}{4} - \frac{9b}{4}F} < \frac{4a+7m}{11} - \sqrt{\frac{16}{121}(a-m)^2 - \frac{18}{11}bF} = \bar{q}_1$ we have $\frac{3}{22}(a-m) + \sqrt{\frac{16}{121}(a-m)^2 - \frac{18}{11}bF} < \sqrt{\frac{(a-m)^2}{4} - \frac{9b}{4}F}$. Simplifying this expression, we yield $\frac{(9bF)^2}{16\cdot(a-m)^2} > 0$. Since this is true, $q_{crit}^{in/in} < \bar{q}_1 < \bar{q}_2$ holds.