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Organizational Decisions in Multistage Production Processes

Verena Nowak*

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Abstract

To explain organizational decisions in multistage production processes we assume a production process with one producer and two suppliers of which one is the firm's direct supplier and the other one is the supplier of the supplier. The firm decides only on the organizational form of her direct supplier who in turn decides on the organizational form of his supplier. Analyzing a scenario of simultaneous production, we find that the decision of the supplier - whether to integrate or outsource his own supplier - is independent from the organizational decision of the producer with respect to her supplier. However, once the production decisions of the firm and the suppliers are made sequentially, the supplier's organizational decisions is no longer independent from that of the producer. More precisely, the supplier's decision to integrate or outsource his own supplier additionally depends on the elasticity of demand and on the importance of the producer for the production process.

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1 Introduction

Firms that subcontract suppliers have to decide whether to choose outsourcing or (vertical) integration of their suppliers. Some firms, as for example Apple, have an overview over the overall supplier structure and decide on the organizational form of all their suppliers: Apple tasks Foxconn or Pegatron, respectively, with the assembly of the iPhone 5. However, according to a list on its web page (see Apple, 2013), Apple has beyond these assembly facilities more than 200 suppliers that provide Apple with the inputs for the iPhone (and its other products). For example, for its iPhone 5, Apple receives instead of a complete camera individual parts from its suppliers. So, the image sensors are provided by Sony or OmniVision, respectively, whereas the lenses are delivered by Largan Precision and Genius Electronic Optical.

However, other firms receive complete modules of their suppliers and thus can only decide on the organizational form of their direct suppliers. This is quite common in the automotive sector where many manufacturing units are modularized. Consider the example of Smart which receives, among other things, complete door and flap modules (Magna Uniport), a cockpit module (Continental) and body panels (Plasta).¹ The direct suppliers of the automotive manufacturers bear the responsibility for the technology and the development of the whole modules. They receive module specification regarding design, shape and surface material but can decide themselves how to implement them. Thus, they choose their own suppliers and their suppliers' organizational forms.²

There are several theories to explain organizational decisions of firms. One important approach is the property rights approach to the organization of firms,³ whose predictions are supported by a multitude of empirical studies.⁴ Until recently, models using the property rights approach did hardly consider the highly relevant sequentiality of production processes, i.e., they did not take into account that production entails several ordered stages such that the direct suppliers of a firm have their own suppliers: While there is a multitude of models with one supplier (see for example Antràs, 2003; Antràs and Helpman, 2004, 2008), there are only some models that deal with more than one supplier at all. Du, Lu, and Tao (2009) analyze a firm's decision whether to conduct bi-sourcing of the manufacturing input, that is, whether the firm uses integrated *and* outsourced suppliers for the production of the input. Van Biesebroeck and Zhang (2011) look at a production process with different intermediate inputs and analyze in a product life-cycle model the sourcing decision of a firm for each supplier independently. However, they focus on the offshoring decision and the decisions on the different suppliers' locations are made independently from each other. The decisions whether to offshore the inputs are only interrelated because the demand for the respective intermediate inputs is interrelated. The other papers can be separated by whether bargaining takes place simultaneously or sequentially: One model where bargaining takes place simultaneously with all suppliers is by Acemoglu, Antràs, and Helpman (2007). They consider multiple, symmetric intermediate inputs and the firm can decide on the range of intermediate inputs employed in the production process (denoted as technology). The firm then simultaneously decides for all inputs whether all suppliers are integrated or outsourced. Schwarz and

¹ Other examples are the complete door modules that Ford utilizes for its Fiesta (Faurecia), the complete door interior panellings of BMW for its 5 Series and the complete door panellings of Mercedes for its CLS Coupés (both Johnson Controls).

² See for example Automotive Netzwerk Suedwestfalen (2013), Daimler (2008), Faurecia (2012) and WIKO (2007).

³ Other major theories are the transaction cost, the managerial incentives and the knowledge capital approach (see, among others, Helpman, 2011; Spencer, 2005).

⁴ See for example Defever and Toubal (2013), Corcos et al. (2012), Bernard et al. (2010), Federico (2010) and Nunn and Trefler (2008).

Suedekum (2013) extend the analysis to production processes that not only comprise intermediate inputs but also headquarter services. They find the empirically relevant phenomenon of hybrid sourcing, where some suppliers are outsourced and others are integrated, when both manufacturing inputs and headquarter services are important for the production process. Nowak, Schwarz, and Suedekum (2013) allow the intermediate inputs to be asymmetric and find that the asymmetries determine which component is more likely to be integrated or outsourced. Antràs and Chor (2013) are the first who analyze a firm's organizational decisions with sequential bargaining. In their model, the production process is an ordered sequence of production stages, each including a different supplier. The firm decides herself on the organizational structure of each supplier. In dependence on the relative size of the elasticity of demand and the degree of substitutability among the different inputs, Antràs and Chor distinguish whether the suppliers' investments are complements or substitutes and find that the firm chooses outsourcing of the upstream suppliers and integration of the downstream suppliers when the investments are complements or vice versa for substitutable investments.

However, their model explains only the organizational decisions of some firms, as for example Apple, whereas it cannot describe the organizational decisions of other firms that do not know all their suppliers, as for example Smart. Additionally, since their results crucially hinge on the relative size of the degree of substitutability and the elasticity of demand and it is hard to measure the substitutability empirically, their results are difficult to test empirically.

Therefore, we provide an alternative mechanism to explain the organizational decisions and assume the suppliers of a firm to decide themselves on the organizational form of their own suppliers. We analyze the implications of this assumption on the organizational decisions. More precisely, we analyze which organizational form a firm chooses for her direct suppliers, which organizational form these suppliers choose in turn for their own suppliers, and especially how these two decisions are interrelated. We can generate the same organizational decisions as Antràs and Chor (2013), however, beyond that, our mechanism can generate complete integration and complete outsourcing of all suppliers. Our results are driven by directly observable measures: the input intensity, the headquarter intensity of production and the elasticity of demand.

In our model, we regard only a segment of the production process and consider a simple model with one firm and two suppliers. We start with the baseline model of Antràs and Helpman (2004) and consider a firm that produces a final good. For the production of this final good, two inputs are necessary - headquarter services and a manufacturing component. Headquarter services are provided by the firm herself, for the production of the manufacturing component a supplier (in the following denoted as supplier 1) is chosen. The firm has to decide on the organizational form of supplier 1 - she can employ a supplier that is integrated within the boundaries of the firm or an unaffiliated supplier. We then extend the model and assume that the production of supplier 1's manufacturing component necessitates two inputs as well. One input is provided by supplier 1, for the other input supplier 1 has to subcontract a supplier himself (in the following denoted as supplier 2). Supplier 1 then has to decide on supplier 2's organizational form, i.e., whether he is integrated or outsourced.

We first analyze a benchmark scenario of complete contracts where no organizational decision is made. Subsequently, we assume contracts to be incomplete such that a hold-up problem arises and each player has an incentive to underinvest. The degree of a player's underinvestment problem depends on the revenue share he receives: The higher is the revenue share a player receives, the lower is the respective player's underinvestment problem. This revenue share is, however, determined by the

firm's or, respectively, the supplier's organizational decision. Since an outsourced supplier can threaten to withhold his input and has thus a higher bargaining power than an integrated supplier that is basically an employee of the firm, he receives a higher revenue share. The essential trade-off underlying both the firm's and supplier 1's organizational decisions is thus between minimizing the own or the other player's underinvestment problem. So the decisions depend on the respective player's importance for the production process.

To later on better understand the effect of sequentiality on the organizational decisions, we first analyze these organizational decisions in the simpler scenario of simultaneous production where the producer and the two suppliers decide on their investments at the same time. In this scenario, the investments of the producer and the two suppliers are lower than with complete contracts - the underinvestment problem arises. As a result, the revenue level is as well lower and the price is higher. With symmetric revenue shares, supplier 1's decision depends solely on the input intensity of the respective supplier, i.e., which supplier's input is more important for the provision of the whole manufacturing input. When supplier 1 is more important, supplier 2 is integrated, and when supplier 2 is more important, supplier 2 is outsourced, such that the respective more important supplier's underinvestment is minimized. In contrast, the organizational decision of the producer is not only driven by the headquarter intensity, i.e., by the importance of headquarter services for the production process, but also by the elasticity of demand and the input intensity. As a result, while the producer's organizational decision depends on supplier 1's decision, supplier 1's decision can be treated independent from the producer's organizational decision with simultaneous production.

We then incorporate sequentiality into the production process and assume supplier 2 to invest previous to the producer and supplier 1. The resulting investment of the three players is still lower than with complete contracts, however, higher than with simultaneous production such that the underinvestment problem is alleviated. The producer's organizational decision depends as in the scenario of simultaneous production on the headquarter intensity, the input intensity and the elasticity of demand. However, due to the sequentiality there is an "anticipation effect" of supplier 2: Since supplier 2 anticipates the producer's investment, his input provision is increasing in the producer's input provision. As a result, supplier 1's organizational decision on supplier 2 is not only driven by the input intensity but also by the headquarter intensity (and the elasticity of demand). As in the scenario of simultaneous production a higher input intensity makes integration of supplier 2 more likely. However, the higher is the headquarter intensity and thus the higher are the producer's investment incentives, the less important it becomes to incentivize supplier 2 for the production such that integration becomes even more likely. These results show that, with sequential production processes, a supplier's decision on the organizational form of his supplier depends on his own organizational form. In more general terms, our model shows that the organizational decisions in different stages of sequential production processes are interrelated and thus cannot be treated independently from each other.

The rest of this paper is organized as follows: In section 2 we introduce the structure of our model. Then, in section 3, we analyze the production process in the benchmark scenario of complete contracts. In section 4 we then assume contracts to be incomplete and analyze the organizational decisions for the scenario of simultaneous and sequential production. Section 5 provides a summary and a discussion of our main results.

2 The Model

2.1 Technology and Demand

We consider a firm that produces a final good y for which two inputs are necessary: headquarter services and a manufacturing component. While headquarter services h are provided by the producer herself, the manufacturing component m is sourced from a supplier (“supplier 1”). These two inputs are combined to the final good by a standard Cobb-Douglas production function:

$$y = \theta_H \left(\frac{h}{\eta_H} \right)^{\eta_H} \left(\frac{m}{1 - \eta_H} \right)^{1 - \eta_H}. \quad (1)$$

θ_H stands for the productivity of the firm, η_H denotes the headquarter intensity of production ($\eta_H \in (0, 1)$) and $\eta_M = 1 - \eta_H$ indicates the component intensity of production. The higher is η_H , the more important are headquarter services for the production of the final good and the lower is the significance of the manufacturing component in the production process.

The model setup so far is the same as in the influential hold-up model of global sourcing by Antràs and Helpman (2004). In their model, Antràs and Helpman do not consider how the manufacturing component is produced, i.e., whether the firm’s (direct) supplier can produce the manufacturing component on his own or whether he has to subcontract an own supplier. This differentiation is irrelevant as long as contracts between the suppliers are complete. However, we are interested in organizational decisions in multistage production processes and since these organizational decisions arise with incomplete contracts, we extend their analysis and assume contracts between the suppliers to be incomplete as well. Thus, in contrast to the model of Antràs and Helpman, we explicitly consider the manufacturing component provided by supplier 1 to be itself composed of two components m_1 and m_2 . While component m_1 is provided by supplier 1 himself, he has to employ a supplier of his own (“supplier 2”) for the production of component m_2 . The two components are again combined to the manufacturing component by a Cobb-Douglas production function:

$$m = \theta_1 \left(\frac{m_1}{\eta_1} \right)^{\eta_1} \left(\frac{m_2}{1 - \eta_1} \right)^{1 - \eta_1}. \quad (2)$$

θ_1 denotes supplier 1’s productivity in generating the manufacturing component, η_1 is supplier 1’s input intensity ($\eta_1 \in (0, 1)$) and $\eta_2 = 1 - \eta_1$ in turn indicates supplier 2’s input intensity. Inserting equation (2) in equation (1), the output of the final good can be depicted as

$$y = \theta_H \left(\frac{h}{\eta_H} \right)^{\eta_H} \left(\frac{\theta_1 \left(\frac{m_1}{\eta_1} \right)^{\eta_1} \left(\frac{m_2}{1 - \eta_1} \right)^{1 - \eta_1}}{1 - \eta_H} \right)^{1 - \eta_H}. \quad (3)$$

The demand function for the final good is assumed to be iso-elastic:

$$y = Ap^{-\frac{1}{1 - \rho}}. \quad (4)$$

Within this equation, A ($A > 1$) is a demand shifter, p is the price of the final good and $1/(1 - \rho)$ denotes the elasticity of demand (with $\rho \in (0, 1)$).

Using equations (3) and (4) gives the revenue of the firm:

$$R = A^{1-\rho} \left[\theta_H \left(\frac{h}{\eta_H} \right)^{\eta_H} \left(\frac{\theta_1 \left(\frac{m_1}{\eta_1} \right)^{\eta_1} \left(\frac{m_2}{1-\eta_1} \right)^{1-\eta_1}}{1-\eta_H} \right)^{1-\eta_H} \right]^\rho. \quad (5)$$

2.2 Organizational Decisions

In our analysis, we focus on the organizational forms chosen for the two suppliers of the manufacturing component - each of the two suppliers can either be vertically integrated within the boundaries of the firm or an external, outsourced supplier. In contrast to Antràs and Chor (2013), who consider the producer to bargain herself with all suppliers along the value chain, we assume the producer to bargain only with her (direct) supplier (supplier 1). Supplier 1 is then assumed to decide on his own on the organizational form of his supplier (supplier 2). For illustration, figure 1 depicts this underlying structure of the production and of the bargaining of Antràs and Chor (2013) and of our model, respectively. In this figure, the solid arrows indicate the flows of inputs, the dashed arrows show the organizational dependencies.

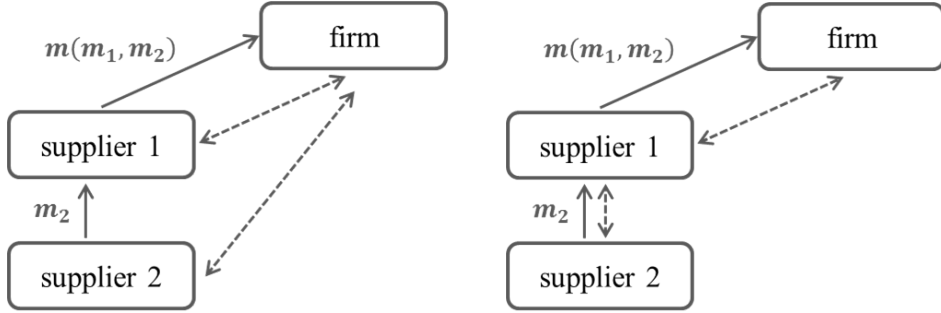


Figure 1: Structure of the production and the bargaining structure.
Left panel: Antràs and Chor (2013). Right panel: our structure.

Consequently, we analyze which organizational form both *the producer and supplier 1* choose for their respective suppliers. In particular, we are interested in the interrelation of these two decisions and want to analyze how supplier 1's decision is affected by the producer's decision.

3 Complete Contracts

In order to subsequently better understand the producer's and supplier 1's organizational decision, we first consider a scenario of complete contracts that leads to the first-best solution and serves as a benchmark in the later analysis. In such a scenario of complete contracts, each player is bounded to provide the inputs in the amount stipulated in the contract - neither player can deviate from the arrangement.⁵ The producer contracts the headquarter services h provided by herself and the suppliers' manufacturing component m provided by supplier 1. Supplier 1 then has to agree by contract with supplier 2 on the input provisions m_1 and m_2 to compile m .

3.1 Structure of the Game

With complete contracts, the production process can be modeled as a 6-stage game with the following timing of events:

1. The firm offers contracts to potential suppliers. These contracts stipulate the suppliers' input provision of the whole manufacturing component m and comprise the (ex post) payment to supplier 1 s_1 and an up-front participation fee τ_1 from supplier 1 that might be positive or negative.
2. There is a huge mass of potential suppliers. Each of these suppliers has an outside option equal to w_1 . The suppliers apply for the contract and the producer chooses one supplier for the production of the manufacturing component.
3. Based on his contract, supplier 1 offers contracts to potential suppliers. These contracts stipulate supplier 2's input provision for the manufacturing component m_2 , the (ex post) payment to supplier 2 s_2 and a (positive or negative) up-front participation fee τ_2 from supplier 2.
4. There is a huge mass of potential suppliers, each with an outside option equal to w_2 , that apply for the contract. Supplier 1 chooses one supplier.
5. The headquarter and supplier 1 and 2 produce their inputs h , m_1 and m_2 , respectively.
6. The final good is produced. Revenue is realized and each player receives the payment stipulated in the contracts.

3.2 Solving the Game

This game is solved by backward induction: In the last stage of the game where the players' inputs are combined to the final good, each player receives the payment specified in the contract, i.e., supplier 1 receives the payment s_1 and supplier 2 receives the payment s_2 while the producer retains the residual $(R - s_1 - s_2)$.

In stage 5, all players produce their inputs in the amounts h , m_1 and m_2 , respectively, as stipulated in the contracts.

For supplier 2 to accept the contract offered by supplier 1 in stage 4, his profit π_2 must be at least equal to his outside option w_2 :

$$\pi_2 = (s_2 - \tau_2) - c_2 m_2 \geq w_2. \quad (6)$$

⁵ Complete contracts also eliminate possible problems associated with input quality. However, in our model we neglect this aspect and focus solely on quantity aspects.

Supplier 2's profit equals the payment from supplier 1 minus his participation fee to supplier 1 and his production costs for the input m_2 ($c_2 m_2$). Since there is no need to leave rents to his supplier, supplier 1 sets the net payment to supplier 2 ($s_2 - \tau_2$) such that supplier 2's profit is exactly equal to the outside option: $s_2 - \tau_2 = c_2 m_2 + w_2$. Thus, supplier 2 receives a net payment that equals his production costs plus his outside option.

In contracting with supplier 2 on how to produce the manufacturing component in stage 3, supplier 1 maximizes his *own* profit

$$\pi_1 = (s_1 - \tau_1) - c_1 m_1 - (s_2 - \tau_2) \quad (7)$$

that is equal to the net payment from the headquarter ($s_1 - \tau_1$) minus supplier 1's production costs for the manufacturing input m_1 ($c_1 m_1$) and the net payment to supplier 2. Using supplier 2's participation constraint, the input provisions m_1 and m_2 are chosen such that the suppliers' total profits

$$\pi_1 = (s_1 - \tau_1) - c_1 m_1 - c_2 m_2 - w_2 \quad (8)$$

are maximized. In the production decision, supplier 1 has to ensure that the suppliers produce the whole manufacturing input m^{cc} specified by the producer's contract in the first stage of the game ($m(m_1, m_2) \stackrel{!}{=} m^{cc}$). Consequently, m_1 and m_2 are chosen to solve

$$\max_{\{m_1, m_2\}} [(s_1 - \tau_1) - c_1 m_1 - c_2 m_2 - w_2] \quad \text{s.t.} \quad \theta_1 \left(\frac{m_1}{\eta_1} \right)^{\eta_1} \left(\frac{m_2}{1 - \eta_1} \right)^{1 - \eta_1} = m^{cc}. \quad (9)$$

Standard maximization gives $m_1/m_2 = c_1/c_2 \eta_1/(1 - \eta_1)$. Supplier 1's input provision is thus *relatively* higher, the higher is the importance of input 1 (η_1) for the production of the manufacturing component and the lower are his own unit costs (c_1). His input provision *relatively* decreases with a higher importance of input 2 ($1 - \eta_1$) for the production of the manufacturing component and with lower unit costs of supplier 2 (c_2).

Using this relation in the constraint in (9), the optimal input provisions of the suppliers are given by

$$m_1^{cc} = \left(\frac{c_2}{c_1} \right)^{1 - \eta_1} \eta_1 \frac{m^{cc}}{\theta_1} \quad \text{and} \quad m_2^{cc} = \left(\frac{c_1}{c_2} \right)^{\eta_1} (1 - \eta_1) \frac{m^{cc}}{\theta_1}. \quad (10)$$

Both suppliers' input provisions positively depend on m^{cc} , whereas a higher productivity of supplier 1 lowers the suppliers' absolute input provisions. The respective supplier's *absolute* input provision is also higher, the lower are his own unit costs and the higher is his input intensity. It decreases with lower unit costs of the other supplier and with a higher input intensity of the other supplier.

In stage 2, supplier 1 accepts the producer's contract only when his profit for the *whole* manufacturing component is at least equal to his outside option w_1 :

$$\pi_1 = (s_1 - \tau_1) - c_M m - w_2 \geq w_1. \quad (11)$$

$c_M m$ denotes the whole manufacturing production costs whereby $c_M = \left(c_1^{\eta_1} c_2^{1 - \eta_1} \right) / \theta_1$ indicates the unit costs of the whole manufacturing component. Since the producer sets the net payment to supplier 1 such that the profits are exactly equal to w_1 , supplier 1 receives the production costs plus both suppliers' outside options as payment from the producer ($s_1 - \tau_1 = c_M m + w_1 + w_2$).

The producer chooses the input provisions h and m that maximize her own profit in stage 1:

$$\pi_H = R - c_H h - (s_1 - \tau_1). \quad (12)$$

Her profit is equal to the revenue of the final good (R) minus her production costs ($c_H h$) and the net payment to supplier 1. Considering supplier 1's participation constraint, the producer chooses the input provisions h and m such that the total payoff

$$\pi_H = R - c_H h - c_M m - w_1 - w_2 \quad (13)$$

is maximized. Standard maximization gives the following relation between the headquarter's and the suppliers' input provision: $h/m = c_M/c_H \eta_H/(1 - \eta_H)$. This expression reflects the interrelations known from the work of Antràs and Helpman (2004): The producer's input provision *relatively* increases with a higher importance of headquarter services (η_H) for the production process and lower own unit costs (c_H). It is, however, relatively lower, the higher is the importance of the manufacturing component ($1 - \eta_H$) for the production process and the lower are the suppliers' unit costs (c_M).

With this expression we can derive the following profit-maximizing input provisions:

$$h^{cc} = \frac{\rho \eta_H}{c_H} R^{cc} \quad \text{and} \quad m^{cc} = \frac{\rho(1 - \eta_H)}{c_M} R^{cc} \quad \text{with} \quad R^{cc} = A \left[\frac{\rho \theta_H}{c_H^{\eta_H} c_M^{1 - \eta_H}} \right]^{\frac{\rho}{1 - \rho}}. \quad (14)$$

These equations show that a player's *absolute* input provision also increases with a higher importance of this player for the production process as well as with lower own unit costs and decreases with a lower importance for the production process and lower unit costs of the other player.

Using m^{cc} and $c_M = (c_1^{\eta_1} c_2^{1 - \eta_1})/\theta_1$, the suppliers' input provisions (of equation (10)) are given by

$$m_1^{cc} = \frac{\rho \eta_1 (1 - \eta_H)}{c_1} R^{cc} \quad \text{and} \quad m_2^{cc} = \frac{\rho (1 - \eta_1) (1 - \eta_H)}{c_2} R^{cc}. \quad (15)$$

Since the whole suppliers' input provision m^{cc} increases in the component-intensity of production ($1 - \eta_H$), the suppliers' respective *absolute* input provisions m_1^{cc} and m_2^{cc} are higher as well.⁶

Using these input provisions, we can determine the overall payoff of the relationship:

$$\pi_H^{cc} = (1 - \rho) R^{cc} - w_1 - w_2. \quad (16)$$

We can furthermore derive the price of the final good:

$$p^{cc} = \frac{c_H^{\eta_H}}{\rho \theta_H} \left(\frac{c_1^{\eta_1} c_2^{1 - \eta_1}}{\theta_1} \right)^{1 - \eta_H}. \quad (17)$$

This price is higher, the higher are the unit costs of the producer and the suppliers. Beyond this, the price is higher the lower is the productivity of the producer for the final good (θ_H) or of supplier 1 for the manufacturing component (θ_1). A higher ρ raises the elasticity of demand $1/(1 - \rho)$ and as a result the price rises as well.

⁶ Note that in this case of complete contracts the input provisions of all three players would be the same if the producer contracted with both suppliers (see Appendix A.1).

4 Incomplete Contracts

In the following we assume contracts between all players to be incomplete - the input investments are considered to be non-contractible since they are too complex to be specified ex ante and non-verifiable to third-parties (as e.g. a court) ex post, as in Grossman and Hart (1986) and Hart and Moore (1990). Therefore, the players renegotiate after the input investments have taken place - a bargaining over the distribution of the surplus arises. Since the investments are furthermore assumed to be fully relationship-specific, hold-up problems arise and each player has an incentive to underinvest. The degree of a player's underinvestment problem depends on the revenue share he expects to receive in the ex post bargaining - the higher is the revenue share a player receives, the lower is his underinvestment problem.

Unlike in the scenario of complete contracts, there is a substantial difference between integrated and outsourced suppliers: Their revenue shares (and as a result the degree of underinvestment) are determined by the suppliers' organizational forms. Since an integrated supplier is essentially an employee of the firm, he can threaten to withhold only a part of his input. In contrast, an outsourced supplier can threaten to withhold his whole input. Thus, an outsourced supplier has a higher bargaining power and receives a higher revenue share than an integrated supplier. Consequently, both the producer and supplier 1 can influence the underinvestment problem through their organizational decisions.

First, we analyze the producer's and supplier 1's organizational decision in a scenario of simultaneous production where the producer and the two suppliers decide at the same time on their input provisions. Subsequently, we assume a sequential production process where supplier 2 invests previous to the producer and supplier 1, and analyze the influence of this sequentiality on the organizational decisions.

4.1 Simultaneous Production

4.1.1 Structure of the Game

In the scenario of incomplete contracts, the above 6-stage game of the production process is extended to the following 9-stage game:

1. The producer chooses the organizational form Ξ_1 of her direct supplier 1. $\Xi_1 = O$ denotes outsourcing and $\Xi_1 = V$ denotes (vertical) integration of supplier 1.
2. Given this organizational decision, the firm offers contracts to potential suppliers. These contracts include an up-front participation fee τ_1 to supplier 1 that might be positive or negative.
3. There is a huge mass of potential suppliers. Each supplier has an outside option equal to w_1 . The suppliers apply for the contract and the producer chooses one supplier for the production of the manufacturing component.
4. This supplier henceforth chooses the organizational form Ξ_2 of his own supplier 2. $\Xi_2 = O$ denotes outsourcing of the supplier and $\Xi_2 = V$ denotes (vertical) integration of the supplier.
5. Based on this decision, supplier 1 offers contracts to potential suppliers. These contracts include again a (positive or negative) up-front participation fee τ_2 to supplier 2.
6. There is a huge mass of potential suppliers with an outside option equal to w_2 that apply for the contract. Supplier 1 chooses one supplier out of this mass.
7. The headquarter and supplier 1 and 2 decide independently on their non-contractible input

provision levels (h , m_1 and m_2 , respectively). Their unit costs of production are c_H , c_1 and c_2 , respectively.

8. Supplier 1 and 2 bargain over the surplus value of their relationship.
9. The producer and supplier 1 bargain over the surplus value of the whole relationship. The final good is produced. Revenue is realized and distributed according to the outcome of the bargaining process.

4.1.2 Solving the Game

As in the scenario of complete contracts, this game is solved by backward induction. In the last stage of the game the final good producer and her direct supplier 1 bargain over the distribution of the surplus value of the relationship. The producer receives a revenue share β_H , supplier 1 receives the remain $(1 - \beta_H)$. These revenue shares depend on the organizational form the producer chooses for supplier 1 in stage 1 that we will analyze below.

In stage 8, both suppliers bargain over the distribution of the suppliers' revenue share $(1 - \beta_H)$ between the suppliers. Supplier 1 receives a revenue share β_1 while supplier 2 receives the residual $(1 - \beta_1)$, whereby the level of β_1 depends on supplier 1's organizational decision in stage 4 that also will be analyzed below.

In stage 7, the producer and the suppliers decide simultaneously on the input provisions for the production of the final good. However, in contrast to the scenario of complete contracts, each player makes his decision independent of the other players. In doing so, he takes into account the revenue share he will receive in the bargaining and chooses the input provision that maximizes his respective profit. More precisely, the producer chooses $h^{sim} = \operatorname{argmax}_h \{\beta_H R - c_H h\}$ while the suppliers choose the profit-maximizing amounts $m_1^{sim} = \operatorname{argmax}_{m_1} \{(1 - \beta_H) \beta_1 R - c_1 m_1\}$ or $m_2^{sim} = \operatorname{argmax}_{m_2} \{(1 - \beta_H) (1 - \beta_1) R - c_2 m_2\}$, respectively. The resulting input provisions are:

$$h^{sim} = \frac{\rho \eta_H \beta_H R^{sim}}{c_H}, \quad m_1^{sim} = \frac{\rho (1 - \eta_H) \eta_1 (1 - \beta_H) \beta_1 R^{sim}}{c_1}$$

$$\text{and } m_2^{sim} = \frac{\rho (1 - \eta_H) (1 - \eta_1) (1 - \beta_H) (1 - \beta_1) R^{sim}}{c_2} \quad (18)$$

$$\text{with } R^{sim} = A \left[\rho \theta_H \left(\frac{\beta_H}{c_H} \right)^{\eta_H} \left(\theta_1 (1 - \beta_H) \left(\frac{\beta_1}{c_1} \right)^{\eta_1} \left(\frac{1 - \beta_1}{c_2} \right)^{1 - \eta_1} \right)^{1 - \eta_H} \right]^{\frac{\rho}{1 - \rho}}$$

Comparing these input provisions and revenue with those calculated in the scenario of complete contracts (equations (14) and (15)), we find that the ratios of the input provisions and the revenue in the two scenarios are a function of the players' revenue shares:

$$\frac{h^{sim}}{h^{cc}} = \psi_{sim} \beta_H < 1,$$

$$\frac{m_1^{sim}}{m_1^{cc}} = \psi_{sim} (1 - \beta_H) \beta_1 < 1,$$

$$\frac{m_2^{sim}}{m_2^{cc}} = \psi_{sim} (1 - \beta_H) (1 - \beta_1) < 1 \quad (19)$$

$$\text{and } \frac{R^{sim}}{R^{cc}} = \psi_{sim} < 1$$

$$\text{with } \psi_{sim} = \left[\beta_1^{(1-\eta_H)\eta_1} (1-\beta_1)^{(1-\eta_H)(1-\eta_1)} (1-\beta_H)^{(1-\eta_H)} \beta_H^{\eta_H} \right]^{\frac{\rho}{1-\rho}} < 1.$$

Since players anticipate that they will not receive the full return of their investment in the ex post bargaining when contracts are incomplete, they have an incentive to provide less input than they would provide with complete contracts. These lower input provisions induce a lower revenue level.

Moreover, we find that, with incomplete contracts, the input provision of the producer or supplier 1, respectively, (and thus the revenue) is higher, the higher is the own revenue share. However, a lower remaining revenue share reduces the respective supplier's investment incentives and thus the whole revenue to be distributed. Therefore, it is important to assign the revenue shares such that both the underinvestment problem of the respective decision maker and his supplier are considered.

In stage 6, supplier 2 applies only for the contract if his profit - that consists of his expected revenue $((1-\beta_1)(1-\beta_H)R^{sim})$ minus his production costs and his participation fee - is at least equal to his outside option w_2 :

$$\begin{aligned} \pi_2^{sim} &= (1-\beta_1)(1-\beta_H)R^{sim} - c_2m_2^{sim} - \tau_2 \\ &= (1-\beta_1)(1-\beta_H[1+\rho(1-\eta_1)(1-\eta_H)])R^{sim} + \tau_2 \geq w_2. \end{aligned} \quad (20)$$

As in the case of complete contracts, supplier 1 chooses the participation fee in stage 5 that equals supplier 2's expected payment minus the production costs and outside option:

$$\begin{aligned} \tau_2 &= (1-\beta_1)(1-\beta_H)R^{sim} - c_2m_2^{sim} - w_2 \\ &= (1-\beta_1)(1-\beta_H[1+\rho(1-\eta_1)(1-\eta_H)])R^{sim} - w_2. \end{aligned} \quad (21)$$

In stage 4, supplier 1 then chooses the organizational form of supplier 2 that maximizes his own profit

$$\begin{aligned} \pi_1^{sim} &= \beta_1(1-\beta_H)R^{sim} - c_1m_1^{sim} - \tau_1 + \tau_2 \\ &= \beta_1(1-\beta_H[1+\rho\eta_1(1-\eta_H)])R^{sim} - \tau_1 + \tau_2. \end{aligned} \quad (22)$$

This profit is equal to supplier 1's expected payment $(\beta_1(1-\beta_H)R^{sim})$ minus his own production costs and his own participation fee to the producer plus supplier 2's participation fee. Using supplier 2's participation constraint (equation (21)), the profit can be rewritten:

$$\begin{aligned} \pi_1^{sim} &= (1-\beta_H)R^{sim} - c_1m_1^{sim} - c_2m_2^{sim} - \tau_1 - w_2 \\ &= (1-\beta_H)[1-\rho(1-\eta_H)[\beta_1\eta_1 + (1-\beta_1)(1-\eta_1)]]R^{sim} - \tau_1 - w_2. \end{aligned} \quad (23)$$

For supplier 1 to participate in the production of the final good in stage 3, this profit must be at least equal to his outside option w_1 such that the participation fee is given by

$$\begin{aligned} \tau_1 &= (1-\beta_H)R^{sim} - c_1m_1^{sim} - c_2m_2^{sim} - w_1 - w_2 \\ &= (1-\beta_H)[1-\rho(1-\eta_H)[\beta_1\eta_1 + (1-\beta_1)(1-\eta_1)]]R^{sim} - w_1 - w_2. \end{aligned} \quad (24)$$

In stage 1, the producer chooses the organizational form of supplier 1 that maximizes his own profit

$$\pi_H^{sim} = \beta_H R^{sim} - c_H h^{sim} + \tau_1 \quad (25)$$

that equals his expected revenue ($\beta_H R^{sim}$) minus his production costs plus supplier 1's participation fee. Using equation (24), the profit becomes

$$\begin{aligned} \pi_H^{sim} &= R^{sim} - c_H h^{sim} - c_1 m_1^{sim} - c_2 m_2^{sim} - w_1 - w_2 \\ &= [1 - \rho [(1 - \beta_H)(1 - \eta_H) [\beta_1 \eta_1 + (1 - \beta_1)(1 - \eta_1)] + \beta_H \eta_H]] R^{sim} - w_1 - w_2. \end{aligned} \quad (26)$$

Comparing this profit level with that in the case of complete contracts gives

$$\frac{\pi_H^{sim}}{\pi_H^{cc}} = \frac{[1 - \rho [(1 - \beta_H)(1 - \eta_H) [\beta_1 \eta_1 + (1 - \beta_1)(1 - \eta_1)] + \beta_H \eta_H]] R^{sim} - w_1 - w_2}{(1 - \rho) R^{sim} - w_1 - w_2}. \quad (27)$$

It can be immediately seen that the profit in the case of incomplete contracts is lower than in the case of complete contracts when assuming zero outside options ($w_1 = w_2 = 0$):

$$\frac{\pi_H^{sim}}{\pi_H^{cc}} = \psi_{sim} \frac{1 - \rho [\beta_H \eta_H + (1 - \beta_H)(1 - \eta_H) [(1 - \beta_1)(1 - \eta_1) + \beta_1 \eta_1]]}{1 - \rho} < 1. \quad (28)$$

However, this result even holds for $w_1 > 0$, $w_2 > 0$. Finally, we can derive the price of the final good:

$$p^{sim} = \frac{1}{\rho \theta_H} \left(\frac{c_H}{\beta_H} \right)^{\eta_H} \left(\frac{c_1^{\eta_1} c_2^{1-\eta_1}}{\theta_1 (1 - \beta_1)^{1-\eta_1} \beta_1^{\eta_1}} \right)^{1-\eta_H}. \quad (29)$$

This price is higher than the price in the scenario of complete contracts:

$$\frac{p^{sim}}{p^{cc}} = \psi_{sim}^{-\frac{1-\rho}{\rho}} > 1. \quad (30)$$

4.1.3 Organizational Decisions

In the next step we analyze which is the organizational form of the respective supplier that maximizes the profit of supplier 1 in stage 4 or that of the producer in stage 1, respectively.

Supplier 1's Organizational Decision We first consider supplier 1's decision on the organizational form of his supplier, supplier 2. Supplier 1 chooses the organizational form that maximizes his profit π_1^{sim} (as given in equation (23)). Thereby, he has the choice between integration and outsourcing. Supplier 1 receives a revenue share β_1^V , when supplier 2 is an integrated supplier, and supplier 1 receives a revenue share β_1^O , when supplier 2 is an outsourced supplier. Supplier 2 receives the residual $(1 - \beta_1^V)$ or $(1 - \beta_1^O)$, respectively. Since supplier 1 has better property rights over supplier 2's component input in case of integration than in case of outsourcing, supplier 1's revenue share is higher when supplier 2 is integrated than when he is outsourced. Vice versa, supplier 2's revenue share is higher when he is outsourced than when he is integrated ($\beta_1^V > \beta_1^O \Leftrightarrow (1 - \beta_1^O) > (1 - \beta_1^V)$).

To decide which organizational form is profit-maximizing, we first derive the optimal revenue share with incomplete contracts and thus assume supplier 1 to be able to freely set his revenue share $\beta_1 \in (0, 1)$, as in Antràs and Helpman (2004, 2008) or Antràs and Chor (2013). With simultaneous

production, supplier 1's maximization problem can be stated as follows:

$$\begin{aligned}
\max_{\beta_1} \pi_1^{sim} &= (1 - \beta_H) [1 - \rho(1 - \eta_H) [\beta_1 \eta_1 + (1 - \beta_1)(1 - \eta_1)]] R^{sim} - \tau_1 - w_2 \\
&= (1 - \beta_H) [1 - \rho(1 - \eta_H) [\beta_1 \eta_1 + (1 - \beta_1)(1 - \eta_1)]] \\
A \left[\rho \theta_H \left(\frac{\beta_H}{c_H} \right)^{\eta_H} \left(\theta_1 (1 - \beta_H) \left(\frac{\beta_1}{c_1} \right)^{\eta_1} \left(\frac{1 - \beta_1}{c_2} \right)^{1 - \eta_1} \right)^{1 - \eta_H} \right]^{\frac{\rho}{1 - \rho}} &- \tau_1 - w_2.
\end{aligned} \tag{31}$$

Differentiating equation (31) with respect to β_1 and solving for β_1 gives the optimal revenue share

$$\begin{aligned}
\beta_1^{sim} &= \beta_1^{sim}(\rho, \eta_1, \eta_H) \\
&= \frac{\sqrt{b_1^{sim}} - (2\eta_1 [1 - \rho([1 - \eta_H][1 - \eta_1] + \eta_H)] + \rho\eta_H)}{2([1 - 2\eta_1][1 - \rho\eta_H])} \text{ with}
\end{aligned} \tag{32}$$

$$b_1^{sim} = (2\eta_1 [1 - \rho([1 - \eta_H][1 - \eta_1] + \eta_H)] + \rho\eta_H)^2 + 4\eta_1 (1 - 2\eta_1) (1 - \rho\eta_H) (1 - \rho[1 - \eta_1][1 - \eta_H]).$$

The black lines in figure 2 illustrate this optimal revenue share β_1^{sim} with respect to η_1 for different values of η_H and ρ . The revenue share in case of outsourcing (β_1^O) is depicted as gray, solid line and the revenue share in case of integration (β_1^V) as gray, dashed line.

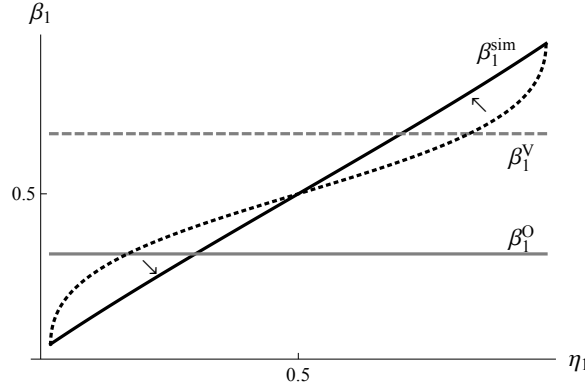


Figure 2: Optimal revenue share β_1^{sim} subject to a variation of η_1 .
Black, dotted line: low values of η_H or ρ . Black, solid line: high values of η_H or ρ .

To minimize his own and supplier 2's underinvestment problem, supplier 1 chooses the organizational form whose revenue share is closest to β_1^{sim} . Supplier 1's decision hence depends on β_1^{sim} 's behaviour of the curve. In the following, we therefore do some comparative statics with respect to the parameters β_1^{sim} depends on, i.e., with respect to η_1 , η_H and ρ .⁷

We start with the analysis of the effects of changes in supplier 1's input intensity η_1 . The derivation of the optimal revenue share β_1^{sim} with respect to supplier 1's input intensity is given by:

$$\frac{\partial \beta_1^{sim}}{\partial \eta_1} > 0. \tag{33}$$

Hence, the optimal revenue share is higher (lower), the higher is the input intensity of supplier 1

⁷ In the main text we only present the sign of the respective derivatives, the concrete derivatives are relegated to the Appendix (A.2).

(supplier 2). In line with Antràs and Helpman (2004), the intuition is that a higher importance of supplier 1's input for the production of the manufacturing input leads to a higher revenue share that he should receive to minimize his own underinvestment problem. Thus, as shown in figure 2, the optimal revenue share is an increasing function of the input intensity η_1 .

In the next step we consider the effect of a change in the headquarter intensity η_H on the optimal revenue share. Differentiating β_1^{sim} with respect to η_H gives

$$\frac{\partial \beta_1^{sim}}{\partial \eta_H} \begin{cases} < 0, & \text{if } \eta_1 < \frac{1}{2} \\ > 0, & \text{if } \eta_1 > \frac{1}{2}. \end{cases} \quad (34)$$

Thus, for $\eta_1 < 1/2$ a rise in the headquarter intensity leads to a decrease of the revenue share while for $\eta_1 > 1/2$ this leads to an increase of the revenue share. A rise of η_H , i.e., a higher importance of headquarter services for the production, implies a lower importance of the whole manufacturing input for the production process. As a result, both suppliers' input provisions decrease (see equation (18)). To provide an incentive for the respective more important supplier, he should receive a larger optimal revenue share. That means, for low values of supplier 1's input intensity, the respective more important supplier 2 should receive a higher revenue share, and vice versa for high values of supplier 1's input intensity.

The last parameter whose influence on β_1^{sim} needs to be analyzed is ρ :

$$\frac{\partial \beta_1^{sim}}{\partial \rho} \begin{cases} < 0, & \text{if } \eta_1 < \frac{1}{2} \\ > 0, & \text{if } \eta_1 > \frac{1}{2}. \end{cases} \quad (35)$$

The optimal revenue share decreases as for a variation of the headquarter intensity with a rise of ρ if $\eta_1 < 1/2$ and increases with ρ if $\eta_1 > 1/2$. To understand this, note that there are two opposing effects of a rise of ρ : On the one hand, a rise of ρ decreases, ceteris paribus, the price $p = (A/y)^{1-\rho}$ such that the revenue decreases. However, on the other hand, a rise of ρ also raises, ceteris paribus, the players' input provisions (h^{sim} , m_1^{sim} and m_2^{sim} as given in equation (18)) and, as a result, the output and the revenue increase. To strengthen the second, positive effect on the revenue it is important to boost the players' input provisions. Since this boosting effect is stronger for the respective more important supplier, this supplier should receive an (optimally) higher revenue share - for $\eta_1 < 1/2$ supplier 2 is more important and β_1^{sim} decreases with ρ and for $\eta_1 > 1/2$ supplier 1 is more important and β_1^{sim} increases with ρ .

These two relations are also depicted in figure 2. The black, dotted line refers to the case where η_H or ρ is low, while the black, solid line refers to the case where η_H or ρ is high. As the derivations predict, the black, dotted line runs above the black, solid line if $\eta_1 < 1/2$ and vice versa if $\eta_1 > 1/2$.

The derivations from above show that the optimal revenue share β_1^{sim} depends on η_1 , η_H and ρ such that supplier 1's organizational decision might vary with respect to all these three parameters. More precisely, since integration is associated with a higher revenue share than outsourcing, we can derive the following predictions:

- i. A higher input intensity η_1 makes integration of supplier 2 more likely.
- ii. If $\eta_1 < 1/2$, a higher headquarter intensity makes outsourcing more likely, and if $\eta_1 > 1/2$, a higher headquarter intensity makes integration more likely.

- iii. If $\eta_1 < 1/2$, a rise of ρ makes outsourcing more likely, and if $\eta_1 > 1/2$ a rise of ρ makes integration more likely.

Resulting from i., we find that for low values of η_1 , β_1^{sim} is closer to β_1^O such that outsourcing of supplier 2 is chosen. For high values of η_1 , β_1^{sim} is closer to β_1^V such that integration of supplier 2 is chosen. Intuitively, the respective more important supplier's underinvestment problem is solved by assigning him a revenue share as high as possible. The resulting organizational decision with respect to the input intensity η_1 is depicted in figure 3.

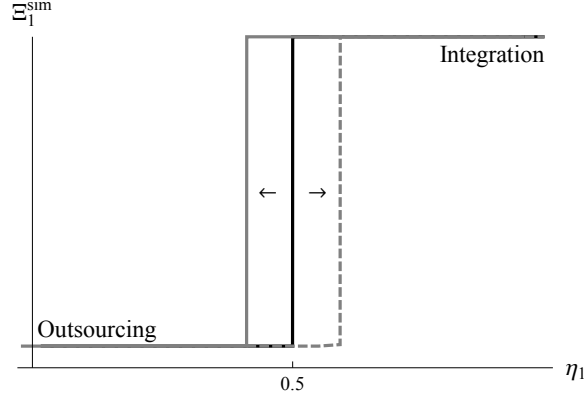


Figure 3: Organizational decision of supplier 1 Ξ_1^{sim} subject to a variation of η_1 .
 Black line: $\beta_1^O = 1 - \beta_1^V$. Gray, solid line: $\beta_1^O < 1 - \beta_1^V$. Gray, dashed line: $\beta_1^O > 1 - \beta_1^V$.

However, as figure 3 illustrates, the level of the input intensity at which the change from outsourcing to integration occurs (the “cutoff input intensity” η_1^{cf}) is subject to variation. We can state that:

PROPOSITION 1 *The cutoff input intensity η_1^{cf} which induces the change in supplier 1’s organizational decision depends on the level of the revenue shares β_1^O and β_1^V , of η_H and of ρ .*

- i. *If β_1^O and β_1^V are symmetric ($\beta_1^O = 1 - \beta_1^V$), there is a clear cutoff input intensity $\eta_1^{cf} = 1/2$ - independent from the level of η_H and ρ .*
- ii. *With asymmetric revenue shares β_1^O and β_1^V ($\beta_1^O \neq 1 - \beta_1^V$), the cutoff input intensity η_1^{cf} differs from $1/2$ and varies with the level of η_H and ρ .*

A higher revenue share β_1^O or β_1^V raises, ceteris paribus, the cutoff input intensity: $\eta_1^{cf} > 1/2$.

A lower revenue shares β_1^O or β_1^V reduces, ceteris paribus, the cutoff input intensity: $\eta_1^{cf} < 1/2$.

Following prediction ii. and iii., the effect of a rise of both η_H and ρ on the optimal revenue share and, thus, on supplier 1’s organizational decision depends on whether $\eta_1 < 1/2$ or $\eta_1 > 1/2$ holds. That means, the critical input intensity η_1^c at which the sign of the derivations with respect to η_H or ρ , respectively, changes is the same for both derivations ($\eta_1^c = 1/2$).

In the special case of symmetric revenue shares, i.e., when β_1^O and β_1^V are located equidistant around β_1^{sim} ($\eta_1 = 1/2$) $\approx 1/2^8$, the cutoff input intensity η_1^{cf} is equal to the critical input intensity $\eta_1^c = 1/2$. Since the effects of η_H and ρ are laterally reversed around $\eta_1 = \eta_1^{cf} = 1/2$, the cutoff input intensity is unaffected by the level of these parameters. The organizational decision for this symmetric case is depicted by the black line in figure 3.

The cutoff input intensity changes once there is an asymmetry in the revenue shares. A higher β_1^V or

⁸ Since $\beta_1^{sim}(\eta_1 = 1/2)$ is indeterminate, knowing that $\partial\beta_1^{sim}/\partial\eta_1 > 0$, we can approximately determine $\beta_1^{sim}(\eta_1 = 1/2)$ using $1/2 [\beta_1^{sim}(\eta_1 = 0.51) + \beta_1^{sim}(\eta_1 = 0.49)] = 1/2$.

β_1^O ($\beta_1^O > (1 - \beta_1^V)$) increases, ceteris paribus, the range in which β_1^{sim} is closer to β_1^O and in which thus outsourcing prevails. As a result, the cutoff input intensity rises and it holds $\eta_1^{cf} > 1/2$. This is illustrated by the gray, dashed line in figure 3. Vice versa, a lower β_1^V or β_1^O ($\beta_1^O < (1 - \beta_1^V)$) reduces the range in which β_1^{sim} is closer to β_1^O such that outsourcing is less prevalent. In this case, the cutoff input intensity falls: $\eta_1^{cf} < 1/2$ (gray, solid line in figure 3). Since the cutoff input intensity and the critical input intensity are no longer equal with asymmetric revenue shares, the cutoff input intensity varies with the level of η_H and ρ .⁹

The Producer's Organizational Decision In the next step we consider the producer's decision in the first stage of the game on the organizational form of her direct supplier, supplier 1. Similar to supplier 1, the producer chooses the organizational form of supplier 1 that maximizes her profit π_H (as given in equation (26)) and is also restricted to choose between integration and outsourcing. The producer's revenue share in case of integration is denoted as β_H^V and that in case of outsourcing is denoted as β_H^O . Supplier 1 receives the residual revenue share $(1 - \beta_H^V)$ or $(1 - \beta_H^O)$, respectively.¹⁰ We again first derive the optimal revenue share. The producer's maximization problem is given by

$$\begin{aligned} \max_{\beta_H} \pi_H^{sim} &= [1 - \rho [(1 - \beta_H)(1 - \eta_H) [\beta_1 \eta_1 + (1 - \beta_1)(1 - \eta_1)] + \beta_H \eta_H]] R^{sim} - w_1 - w_2 \\ &= [1 - \rho [(1 - \beta_H)(1 - \eta_H) [\beta_1 \eta_1 + (1 - \beta_1)(1 - \eta_1)] + \beta_H \eta_H]] \\ &A \left[\rho \theta_H \left(\frac{\beta_H}{c_H} \right)^{\eta_H} \left(\theta_1 (1 - \beta_H) \left(\frac{\beta_1}{c_1} \right)^{\eta_1} \left(\frac{1 - \beta_1}{c_2} \right)^{1 - \eta_1} \right)^{1 - \eta_H} \right]^{\frac{\rho}{1 - \rho}} - w_1 - w_2. \end{aligned} \quad (36)$$

Differentiating equation (36) with respect to β_H and solving for β_H gives the optimal revenue share

$$\begin{aligned} \beta_H^{sim} &= \beta_H^{sim}(\rho, \beta_1, \eta_1, \eta_H) \\ &= \frac{\eta_1 + (2 - \eta_1) \eta_H (1 - \rho (1 - \eta_H)) + \beta_1 (1 - 2\eta_1) (1 - \eta_H) (1 + \rho \eta_H) \sqrt{(1 - \eta_H) b_H^{sim}}}{2(\eta_H - (1 - \eta_H)((1 - \eta_1) - \beta_1(1 - 2\eta_1))} \\ \text{with } b_H^{sim} &= \sqrt{(4(1 - \rho) \eta_H + (1 - \eta_H)(\eta_1 + \rho(2 - \eta_1) \eta_H + \beta_1(1 - 2\eta_1)(1 - \rho \eta_H))^2)} \end{aligned} \quad (37)$$

In figure 4, we depict the producer's optimal revenue share β_H^{sim} (black, solid line) subject to a variation of η_H for given values of η_1 and ρ . This optimal revenue share also depends on the revenue share supplier 1 receives (β_1). To avoid distortions of the effects, we assume that supplier 1 chooses the organizational form of supplier 2 that maximizes his profits and that $\beta_1^O = (1 - \beta_1^V)$ holds such that - following proposition 1 - supplier 1 chooses $\beta_1 = \beta_1^O$ if $\eta_1 < 1/2$ and $\beta_1 = \beta_1^V$ if $\eta_1 > 1/2$. The gray, solid line depicts the producer's revenue share in case of outsourcing (β_H^O) and the gray, dashed line depicts the producer's revenue share in case of integration (β_H^V).

Since the producer chooses the organizational form whose revenue share is closest to β_H^{sim} , we analyze the effect of variations of η_1 , η_H and ρ on the producer's optimal revenue share β_H^{sim} .¹¹

⁹ An alternative approach to determine supplier 1's profit-maximizing organizational decision is to compare the profits in case of outsourcing and integration (see Appendix A.3). The resulting organizational decision is identical.

¹⁰ Note that the revenue share supplier 1 receives is the whole suppliers' revenue share that is distributed between the two suppliers. In the end, supplier 1 gets only a fraction $\beta_1(1 - \beta_H)$ of the revenue.

¹¹ As above, we only present the sign of the respective derivatives in the main text and relegate the concrete derivatives to the Appendix (A.4).

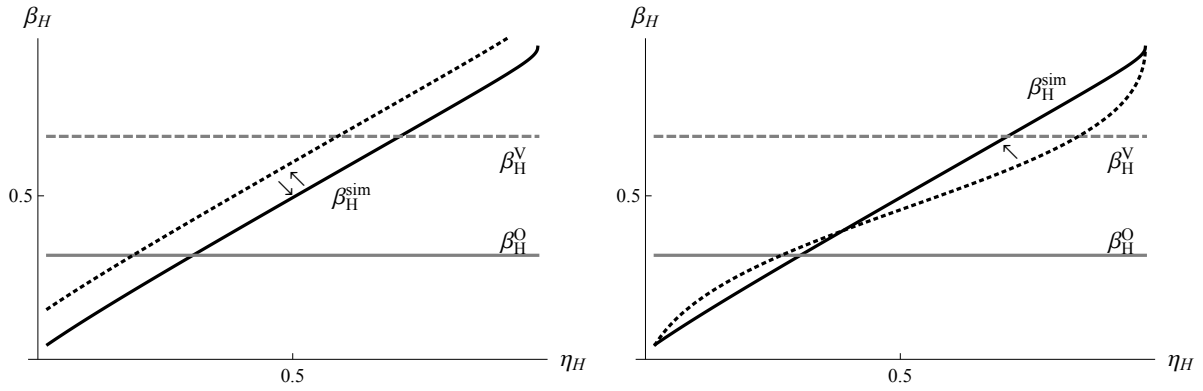


Figure 4: Optimal revenue share β_H^{sim} subject to a variation of η_H .

Left panel: Black, dotted line: low or high values of η_1 . Black, solid line: intermediate values of η_1 .

Right panel: Black, dotted line: low values of ρ . Black, solid line: high values of ρ .

The derivation of the optimal revenue share β_H^{sim} with respect to the headquarter intensity is given by

$$\frac{\partial \beta_H^{sim}}{\partial \eta_H} > 0. \quad (38)$$

Thus, as illustrated in both panels of figure 4, the producer's optimal revenue share is increasing in the level of the headquarter intensity of production.

To analyze the effect of changes of supplier 1's input intensity η_1 , we differentiate β_H^{sim} with respect to η_1 :

$$\frac{\partial \beta_H^{sim}}{\partial \eta_1} \begin{cases} < 0, & \text{if } \eta_1 < \frac{1}{2} \\ > 0, & \text{if } \eta_1 > \frac{1}{2}. \end{cases} \quad (39)$$

Interestingly, this derivation is independent from the level of headquarter intensity and is smaller than 0 if $\eta_1 < 1/2$ and larger than 0 if $\eta_1 > 1/2$. The intuition for this finding is the following: When η_1 rises, the importance of headquarter services for the production remains constant, however, the suppliers' investment incentives change. Since the producer anticipates supplier 1's organizational decision with respect to supplier 2, he also anticipates the effects of these changes. If $\eta_1 < 1/2$, supplier 1 chooses outsourcing of supplier 2 and receives a smaller fraction of the suppliers' revenue share than supplier 2: $\beta_1^O < (1 - \beta_1^O)$. Thus, when η_1 rises, supplier 1's input provision increases, however, it increases less than supplier 2's input provision decreases. As a result, the level of the manufacturing input and, thus, the revenue level would decrease. To avoid this, the producer wants to strengthen the suppliers' production incentives by assigning them a larger share of the revenue ($(1 - \beta_H^{sim})$ increases, β_H^{sim} decreases). Contrary, if $\eta_1 > 1/2$, supplier 1 chooses integration of supplier 2 and his fraction of the suppliers' revenue share is higher than supplier 2's fraction: $\beta_1^V > (1 - \beta_1^V)$. An increase of η_1 then leads to a higher increase of supplier 1's input provision than the decrease of supplier 2's input provision. As a result, the level of the manufacturing input and the revenue level increase and it is not so important for the producer to incentivize the suppliers. Instead, she can assign herself a larger share of the revenue (β_H^{sim} increases, $(1 - \beta_H^{sim})$ decreases). This relation is illustrated in the left panel of figure 4. The black, solid line represents the producer's optimal revenue share for intermediate values of η_1 and the black, dotted line depicts this revenue share for low or high values of η_1 . Independent from the level of headquarter-intensity the black, dotted line runs above the black, solid line. With a rise of η_1 the black, dotted line first converges to the black, solid line, however, once $\eta_1 > 1/2$ holds

the black, dotted line diverges from the black, solid line.

The last parameter who influences β_H^{sim} 's behaviour of the curve is ρ :

$$\frac{\partial \beta_H^{sim}}{\partial \rho} \begin{cases} < 0, & \text{if } \eta_H \text{ is small} \\ > 0, & \text{if } \eta_H \text{ is high.} \end{cases} \quad (40)$$

For low values of the headquarter intensity η_H a rise of ρ decreases the producer's optimal revenue share β_H^{sim} , for high values of η_H a rise of ρ raises β_H^{sim} . The intuition for this finding is similar to the intuition for the effect of ρ on β_1^{sim} above: On the one hand, a rise of ρ reduces the price and hence decreases the revenue, however, on the other hand, it raises the producer's and the suppliers' investments and thus increases the revenue. To strengthen the second, positive effect on the revenue, it is important to properly incentivize the respective more important player: For small values of the headquarter intensity the investment increase caused by ρ is relatively smaller for the producer than for the suppliers. To boost the suppliers' investments, the producer would like to assign them a higher revenue share ($(1 - \beta_H^{sim})$ increases, β_H^{sim} decreases). Vice versa, for high values of η_H , a rise of ρ induces a larger investment increase for the producer than for the suppliers such that the producer would like to assign herself a higher revenue share (β_H^{sim} increases, $(1 - \beta_H^{sim})$ decreases). This relation is illustrated in the right panel of figure 4 where the black, solid line depicts high values of ρ and the black, dotted line represents low values of ρ . For low values of η_H , the black, dotted line runs above the black, solid line and vice versa for high values of η_H . The critical value η_H^c at which the sign of the derivation with respect to ρ changes is not equal to $1/2$. Since the producer anticipates the supplier's decision, η_H^c depends on supplier 1's input intensity η_1 : η_H^c first falls with a rise of η_1 (if $\eta_1 < 1/2$) and then increases with a rise of η_1 (if $\eta_1 > 1/2$). As explained above, for $\eta_1 < 1/2$ a rise of η_1 decreases the level of the manufacturing input. The higher is η_1 (i.e., the more similar are η_1 and $(1 - \eta_1)$), the lower is this level. To boost the revenue level, it becomes increasingly important to incentivize the producer and the critical value η_H^c decreases. Contrary, for $\eta_1 > 1/2$ a rise of η_1 comes along with an increase of the level of the manufacturing component. The higher is η_1 , the larger becomes this level such that it is more important to incentivize the suppliers. As a result, the critical value η_H^c increases with η_1 .

Since the producer's optimal revenue share varies with η_H , η_1 and ρ , the producer's organizational decision depends on these parameters as well. From the derivations we can derive predictions of the producer's organizational decision:

- i. A higher headquarter intensity makes integration more likely.
- ii. If $\eta_1 < 1/2$, a higher input intensity of supplier 1 makes outsourcing more likely, and if $\eta_1 > 1/2$, a higher input intensity of supplier 1 makes integration more likely.
- iii. If η_H is small, a rise of ρ makes outsourcing more likely, and if η_H is high, a rise of ρ makes integration more likely.

Following prediction i., for low values of η_H β_H^{sim} is closer to β_H^O such that outsourcing of supplier 1 is chosen and for high values of η_H integration of supplier 1 is chosen. The resulting organizational decision under the assumption of symmetric revenue shares ($\beta_H^O = (1 - \beta_H^V)$) is depicted in figure 5.

Interestingly, since the producer anticipates supplier 1's decision and the effects of her own decision on the suppliers, the level of headquarter intensity which causes the change in the producer's organizational decision (the "cutoff headquarter intensity η_H^{cf} ") varies, although we assume symmetric revenue

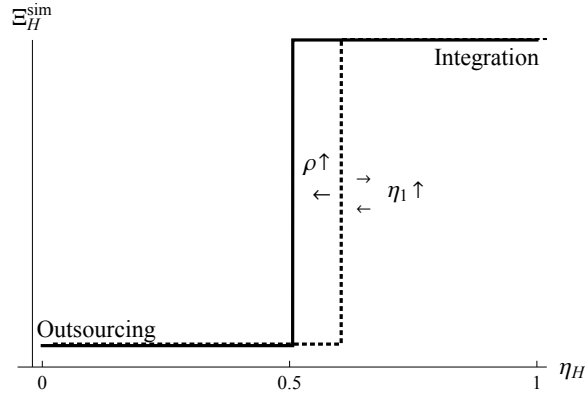


Figure 5: Organizational decision of the producer Ξ_H^{sim} subject to a variation of η_H .
Black, dotted line: low values of ρ . Black, solid line: high values of ρ .

shares. More precisely holds:

PROPOSITION 2 *Assuming that $\beta_1^O = (1 - \beta_1^V)$ and $\beta_H^O = (1 - \beta_H^V)$, the cutoff headquarter intensity η_H^{cf} at which the change in the producer’s organizational decision arises depends on the level of η_1 and ρ :*

- i. The more similar are the suppliers in their importance for the manufacturing input, the more likely becomes outsourcing of supplier 1.*
- ii. A higher ρ makes integration more likely.*

We know from prediction ii. that the direction of the effect of an increase of η_1 on the producer’s optimal revenue share and as a result on the producer’s organizational decision depends on the level of η_1 . The critical value of input intensity at which there is a change in the direction of the effect is $\eta_1^c = 1/2$. Since an increase of η_1 first increases and then decreases the prevalence of outsourcing, and thus the cutoff headquarter intensity, outsourcing is most prevalent for $\eta_1 = \eta_1^c = 1/2$, i.e., when the suppliers are equally important for the manufacturing input. The higher is the asymmetry in the suppliers’ input intensities, the less prevalent becomes outsourcing. Since the direction of the shift of the optimal revenue share is the same for all levels of the headquarter intensity, the relation also holds for asymmetric revenue shares β_H^O and β_H^V .

Prediction iii. indicates that a rise of ρ raises the cutoff headquarter intensity if η_H is “low” and reduces this intensity if η_H is “high”. The critical value of headquarter intensity that separates the “low” and “high” values is not constant but subject to variation. Using numerical simulations, we find that the critical value is strictly lower than 1/2. Therefore, as long as β_H^O and β_H^V are symmetrical, a rise of ρ increases the prevalence of integration.¹²

Interrelation of the producer’s and supplier 1’s organizational decisions To illustrate the relation of the organizational decisions with simultaneous production, we merge the producer’s and supplier 1’s decision in one figure: Figure 6 illustrates the resulting combined organizational decisions of both the producer (Ξ_H^{sim}) and supplier 1 (Ξ_1^{sim}) under the assumption of symmetric revenue shares as $\Xi^{sim} = \{\Xi_H^{sim}, \Xi_1^{sim}\}$. “O” denotes outsourcing of the respective supplier and “V” stands for integration. On the horizontal axis, we display the headquarter intensity η_H and on the vertical axis

¹²The producer’s profit-maximizing organizational decision on supplier 1 can also be determined by comparing the profits in case of outsourcing and integration (see Appendix A.5). As for the decision of supplier 1, the results are identical.

the input intensity η_1 .

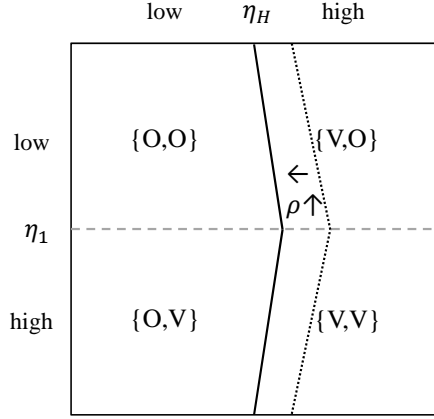


Figure 6: Organizational decisions of the producer and supplier 1 with simultaneous production.
 Black, dotted line: low values of ρ . Black, solid line: high values of ρ .
 Gray, dashed line: all values of ρ .

As figure 6 shows, there result four different combined organizational decisions: $\{O, O\}$, $\{O, V\}$, $\{V, O\}$ and $\{V, V\}$. The organizational decision of supplier 1 depends on the level of input intensity: When η_1 is low, i.e., when η_1 is above the gray, dashed line, supplier 1 chooses outsourcing and when η_1 is high, i.e., when η_1 is below this line, he chooses integration of supplier 2. Since this line varies neither with η_H nor with ρ , figure 6 illustrates that supplier 1's decision is solely driven by η_1 . The organizational decision of the producer is a function of the headquarter intensity: For low values of η_H , i.e., when η_H is to the left of the black, solid line or the black, dotted line, respectively, the producer chooses outsourcing of supplier 1. Vice versa, for high values of η_H , i.e., when η_H is to the right of the respective line, the producer chooses integration. In contrast to the separating line of the input intensity, the line that separates low and high values of the headquarter intensity is not constant, but varies with η_1 and ρ . The black, dotted line represents low values of ρ and the black, solid line stands for high values of ρ . Thus, a higher elasticity of demand shifts the separating line to the left such that integration becomes more prevalent. In addition, the separating line is not straight but curved: The more similar are the suppliers in their importance, the more is the line tilted to the right. As a result, the range in which the producer chooses outsourcing of supplier 1 increases.

Using Proposition 1 and 2 and this figure we can state the following result:

PROPOSITION 3 *Assuming $\beta_1^O = 1 - \beta_1^V$ and $\beta_H^O = 1 - \beta_H^V$ and simultaneous production, the producer's decision depends on supplier 1's decision, however, the organizational decision of supplier 1 is independent from the producer's organizational decision.*

In the following, we compare these results for the simultaneous scenario with those of the sequential model of Antràs and Chor (2013). In doing so, it is important to note that they consider a measure one of production stages (and thus suppliers) while we only assume two suppliers. Adopting their notation of “upstream” and “downstream” stages, each stage thus comprises only one supplier; supplier 2 is the upstream supplier and supplier 1 is the downstream supplier. Due to this discrepancy in the number of stages, it is clear from the beginning on that our results are rougher than theirs. In their model, Antràs and Chor find a positive relationship between the headquarter intensity and the range of stages that are integrated. Since in our model the decision on the organizational form of the upstream supplier 2 is independent from the headquarter intensity, we do not have an effect

on the upstream stage. However, consistently with their result, our analysis shows that a higher headquarter intensity raises the prevalence of integration within the downstream stage. With respect to the elasticity of demand, Antràs and Chor find that a higher ρ reduces the range of stages that are vertically integrated. This is contrary to our findings: On the one hand, a rise of ρ has no effect on the organizational decision in the upstream stage. On the other hand, a higher elasticity of demand increases the prevalence of integration in the downstream stage. However, in the Antràs-Chor-model, a rise of ρ might have an additional effect: Since they distinguish sequential complements and substitutes depending on the level of the elasticity of demand and the elasticity of substitution, a rise of ρ may, *ceteris paribus*, induce a change from sequential substitutes to sequential complements. As a result, instead of integration of upstream stages and outsourcing of downstream stages outsourcing of upstream stages and integration of downstream stages arises. This is consistent to what we find, namely that integration in the downstream stage becomes more prevalent. Since the input intensity - that is crucial for the organizational decision in both the upstream and the downstream stage in our model - is not part of the analysis of Antràs and Chor, we cannot check the consistency.

4.2 Sequential Production

So far, we have assumed that the producer and the suppliers invest at the same point of time, i.e., a simultaneous production process. However, investments can take place at different points of time. In the following, to better compare our results to those of Antràs and Chor (2013), we consider such a sequentiality of the production process and assume supplier 2 to invest previous to the producer and supplier 1.¹³

4.2.1 Structure of the Game

With sequentiality of production, the seventh stage of the game structure described in section 4.1.1 is split in two separate stages:

7. a. Supplier 2 decides on his non-contractible input provision level (m_2).
- b. After the production of m_2 , the producer and supplier 1 decide simultaneously on their non-contractible input provision levels (h and m_1 , respectively).

4.2.2 Solving the Game

Solving by backward induction, in stage 7.b supplier 1 and the producer first choose the input provisions that maximize their respective own profit. The profit-maximizing input provisions are as for simultaneous production (equation (18)) given by

$$h^{seq} = \frac{\rho\eta_H\beta_H R^{seq}}{c_H} \quad \text{and} \quad m_1^{seq} = \frac{\rho(1-\eta_H)\eta_1(1-\beta_H)\beta_1 R^{seq}}{c_1}. \quad (41)$$

¹³We could further expand the sequentiality of the production process and additionally assume supplier 1 to invest previous to the producer. However, in order to avoid the mixing of different effects we only assume supplier 2 to invest previous to the other players.

However, in contrast to the prior analysis, the revenue R^{seq} cannot be finally determined at this stage since it depends additionally on supplier 2's input provision:

$$R^{seq} = \left(A^{1-\rho} \left[\rho^{1-\frac{1-\phi}{\rho}} \left(\frac{\beta_H}{c_H} \right)^{\eta_H} \left(\left[\frac{\beta_1(1-\beta_H)}{c_1} \right]^{\eta_1} \left[\frac{m_2}{(1-\eta_1)(1-\eta_H)} \right]^{1-\eta_1} \right)^{1-\eta_H} \right]^{\rho} \right)^{\frac{1}{\phi}} \quad (42)$$

$$\text{with } \phi = 1 - \rho(1 - [1 - \eta_1][1 - \eta_H]) < 1.$$

When supplier 2 decides in stage 7.a on this input provision, he anticipates supplier 1's and the producer's input provisions and thus this revenue level and chooses $m_2^{seq} = \operatorname{argmax}_{m_2} \{(1 - \beta_H)(1 - \beta_1)R^{seq} - c_2 m_2\}$ is maximized. This gives his profit-maximizing input provision:

$$m_2^{seq} = \frac{\rho(1 - \eta_H)(1 - \eta_1)(1 - \beta_H)(1 - \beta_1)R^{seq}}{c_2 \phi} \quad (43)$$

$$\text{with } R^{seq} = A \left[\rho \theta_H \left(\frac{\beta_H}{c_H} \right)^{\eta_H} \left(\theta_1(1 - \beta_H) \left(\frac{\beta_1}{c_1} \right)^{\eta_1} \left(\frac{1 - \beta_1}{c_2 \phi} \right)^{1-\eta_1} \right)^{1-\eta_H} \right]^{\frac{\rho}{1-\rho}}.$$

Comparing supplier 2's input provision and the revenue level to those in the scenario of simultaneous production (equation (18)), we find that both the input provision and the revenue level are now inversely related to ϕ , i.e., they are both higher with sequential production than with simultaneous production: Since supplier 2 anticipates the producer's and supplier 1's investments, he invests more than with sequential production - independent of the revenue level (equation (43)). This higher investment raises the revenue and thus, supplier 2's investment further increases:

$$\frac{m_2^{seq}}{m_2^{sim}} = \psi_{seq}^{\frac{1-\rho}{\rho(1-\eta_1)(1-\eta_H)} + 1} \gg 1$$

$$\text{and } \frac{R^{seq}}{R^{sim}} = \psi_{seq} > 1 \quad (44)$$

$$\text{with } \psi_{seq} = \phi^{-\frac{\rho(1-\eta_1)(1-\eta_H)}{1-\rho}} = \phi^{1-\frac{\phi}{1-\rho}} > 1.$$

As a result, the producer's and supplier 1's investments are higher as well:

$$\frac{h^{seq}}{h^{sim}} = \frac{m_1^{seq}}{m_1^{sim}} = \psi_{seq} > 1. \quad (45)$$

Thus, in our analysis the players' investments are (always) sequential complements. This is contrary to the analysis of Antràs and Chor (2013) where the investments can be sequential complements or sequential substitutes - depending on the level of the elasticity of substitution and the level of the elasticity of demand. Using equations (41) and (43), supplier 1's profit for sequential production can be depicted as:

$$\pi_1^{seq} = (1 - \beta_H) \left[1 - \rho(1 - \eta_H) \left[\beta_1 \eta_1 + \frac{(1 - \beta_1)(1 - \eta_1)}{\phi} \right] \right] R^{seq} - \tau_1 - w_2. \quad (46)$$

Proceeding as in the scenario of simultaneous production gives the payoff of the relationship:

$$\pi_H^{seq} = \left[1 - \rho \left[(1 - \beta_H)(1 - \eta_H) \left[\beta_1 \eta_1 + \frac{(1 - \beta_1)(1 - \eta_1)}{\phi} \right] + \beta_H \eta_H \right] \right] R^{seq} - w_1 - w_2. \quad (47)$$

Comparing the payoffs of both scenarios we find:

$$\frac{\pi_H^{seq}}{\pi_H^{sim}} = \frac{\left[1 - \rho \left[(1 - \beta_H) (1 - \eta_H) \left[\beta_1 \eta_1 + \frac{(1 - \beta_1)(1 - \eta_1)}{\phi} \right] + \beta_H \eta_H \right] \right] R^{seq} - w_1 - w_2}{\left[1 - \rho \left[(1 - \beta_H) (1 - \eta_H) \left[\beta_1 \eta_1 + (1 - \beta_1) (1 - \eta_1) \right] + \beta_H \eta_H \right] \right] R^{sim} - w_1 - w_2}. \quad (48)$$

Assuming zero outside options ($w_1 = w_2 = 0$), it is easy to see that the payoff with sequential production is higher than the payoff with simultaneous production (equation (26)):¹⁴

$$\frac{\pi_H^{seq}}{\pi_H^{sim}} = \Psi_{seq} \frac{\left[1 - \rho \left[(1 - \beta_H) (1 - \eta_H) \left[\beta_1 \eta_1 + \frac{(1 - \beta_1)(1 - \eta_1)}{\phi} \right] + \beta_H \eta_H \right] \right]}{\left[1 - \rho \left[(1 - \beta_H) (1 - \eta_H) \left[\beta_1 \eta_1 + (1 - \beta_1) (1 - \eta_1) \right] + \beta_H \eta_H \right] \right]} > 1. \quad (49)$$

However, this result holds as well for positive outside options ($w_1 > 0, w_2 > 0$). Simple maths shows that the price is given by:

$$p^{seq} = \frac{1}{\rho \theta_H} \left(\frac{c_H}{\beta_H} \right)^{\eta_H} \left(\frac{c_1^{\eta_1} c_2^{1 - \eta_1}}{\theta_1 (1 - \beta_1)^{1 - \eta_1} \beta_1^{\eta_1}} \right)^{1 - \eta_H} \phi^{(1 - \eta_1)(1 - \eta_H)}. \quad (50)$$

Comparing the prices with sequential and simultaneous production (equation (29)), we find that the price is lower with sequential production than with simultaneous production:

$$\frac{p^{seq}}{p^{sim}} = \Psi_{seq}^{-\frac{1 - \rho}{\rho}} < 1. \quad (51)$$

However, the input provisions, the revenue level and the profit level are still lower and the price is still higher than with complete contracts:

$$\begin{aligned} \frac{h^{seq}}{h^{cc}} &= \psi_{sim} \psi_{seq} \beta_H < 1, \\ \frac{m_1^{seq}}{m_1^{cc}} &= \psi_{sim} \psi_{seq} \beta_1 (1 - \beta_H) < 1, \\ \frac{m_2^{seq}}{m_2^{cc}} &= \psi_{sim} \psi_{seq}^{\frac{1 - \rho}{\rho(1 - \eta_1)(1 - \eta_H)} + 1} (1 - \beta_1) (1 - \beta_H) < 1, \\ \frac{R^{seq}}{R^{cc}} &= \psi_{sim} \psi_{seq} < 1, \end{aligned} \quad (52)$$

$$\begin{aligned} \frac{\pi_H^{seq}}{\pi_H^{cc}} &= \psi_{sim} \psi_{seq}^{\frac{1 - \rho}{\rho(1 - \eta_1)(1 - \eta_H)} + 1} \frac{1 - \rho \left[\beta_H \eta_H + (1 - \beta_H) (1 - \eta_H) \left[\frac{(1 - \beta_1)(1 - \eta_1)}{\phi} + \beta_1 \eta_1 \right] \right]}{1 - \rho} < 1 \\ \text{and } \frac{p^{seq}}{p^{cc}} &= (\psi_{sim} \psi_{seq})^{-\frac{1 - \rho}{\rho}} > 1 \end{aligned}$$

The intuition is that with sequential production processes, there are two effects: On the one hand, there is supplier 2's anticipation effect that raises the input provisions, the revenue level and the profit level and reduces the price ($\psi_{seq} > 1$). On the other hand, contract incompleteness leads to an underinvestment in terms of lower input provisions, a lower revenue level, lower profits and a higher

¹⁴ More precisely, there are two countervailing effects on the relative payoff: On the one hand, the revenue with sequential production is higher than with simultaneous production. On the other hand, due to the higher input provisions, the costs are higher as well. Since the first effect is stronger than the second one, the payoff is higher with sequential production than with simultaneous production.

price ($\psi_{sim} < 1$). The second, negative effect exceeds the first, positive effect such that in the scenario of sequential production, the input provisions, the revenue level and the profit are still lower than in the case of complete contracts and the price is still higher. Thus, sequentiality of the production process does not eliminate the underinvestment problem, however, sequentiality reduces it.¹⁵

4.2.3 Organizational Decisions

Based on these interrelations we can determine in the following the influence of sequentiality on the organizational decision supplier 1 and the producer make in stage 4 or stage 1, respectively.

Supplier 1's Organizational Decision Considering supplier 1's organizational decision first, we can state supplier 1's maximization problem with sequential production as

$$\begin{aligned} \max_{\beta_1} \pi_1^{seq} &= (1 - \beta_H) \left[1 - \rho(1 - \eta_H) \left[\beta_1 \eta_1 + \frac{(1 - \beta_1)(1 - \eta_1)}{\phi} \right] \right] R^{seq} - \tau_1 - w_2 \\ &= (1 - \beta_H) \left[1 - \rho(1 - \eta_H) \left[\beta_1 \eta_1 + \frac{(1 - \beta_1)(1 - \eta_1)}{\phi} \right] \right] \\ &A \left[\rho \theta_H \left(\frac{\beta_H}{c_H} \right)^{\eta_H} \left(\theta_1 (1 - \beta_H) \left(\frac{\beta_1}{c_1} \right)^{\eta_1} \left(\frac{1 - \beta_1}{c_2 \phi} \right)^{1 - \eta_1} \right)^{1 - \eta_H} \right]^{\frac{\rho}{1 - \rho}} - \tau_1 - w_2. \end{aligned} \quad (53)$$

Derivating this profit level with respect to the revenue share and solving for β_1^{seq} gives

$$\begin{aligned} \beta_1^{seq} &= \beta_1^{seq}(\rho, \eta_1, \eta_H) \\ &= \frac{\sqrt{b_1^{seq}} - \rho \eta_1^2 (1 - \eta_H) (\phi + \rho) - \eta_1 (2 - \rho(3 - \rho \eta_H))}{2(1 - \rho \eta_H) (1 - \eta_1 (1 + \phi))} \quad \text{with} \end{aligned} \quad (54)$$

$$\mu = 4 [1 - \rho] [1 - \rho \eta_H] [1 - \eta_1 (1 + \phi)] + \eta_1 \left[2 + \rho^2 \left([1 - \eta_1] \eta_1 [1 - \eta_H]^2 + \eta_H \right) - \rho (3 - \eta_1 [1 - \eta_H]) \right]^2.$$

Analogously to figure 2, figure 7 depicts supplier 1's optimal revenue share β_1^{seq} with respect to η_1 for different values of ρ and η_H . The gray, solid line illustrates the revenue share in case of outsourcing and the gray, dashed line illustrates the revenue share in case of integration.

When determining β_1^{seq} 's behaviour of the curve, i.e., when differentiating this revenue share with respect to η_1 , η_H and ρ , there arise two differences compared to the scenario of simultaneous production: First, the derivation of supplier 1's optimal revenue share β_1^{seq} with respect to η_H is independent from the level of η_1 positive:

$$\frac{\partial \beta_1^{seq}}{\partial \eta_H} > 0. \quad (55)$$

This implies that a rise of the headquarter intensity raises the optimal revenue share β_1^{seq} for all suppliers' input intensities, i.e., irrespective of which supplier is relatively more important for the production of the whole manufacturing input. The intuition is supplier 2's anticipation: Ignoring effects on the revenue level, a higher importance of headquarter services, i.e., a lower importance of the component, for the production causes, ceteris paribus, lower input provisions of both suppliers.

¹⁵This finding is in line with Zhang and Zhang (2013) who introduce sequentiality in Hart's 1995 model of one producer and one supplier bargaining about the ownership of the firm.

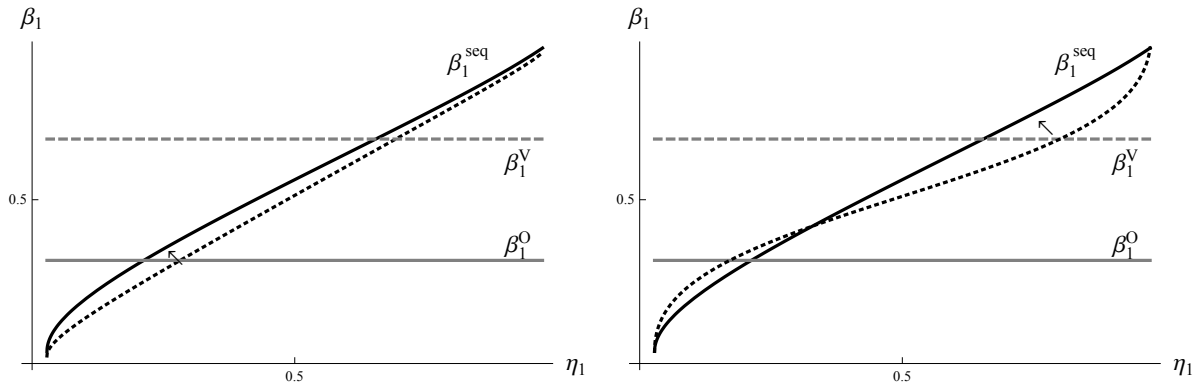


Figure 7: Optimal revenue share β_1^{seq} subject to a variation of η_1 .
Left panel: Black, dotted line: low values of η_H . Black, solid line: high values of η_H .
Right panel: Black, dotted line: low values of ρ . Black, solid line: high values of ρ .

However, since a rise of η_H also increases the producer's input provision, supplier 2's anticipation rises. As a result, his input provision increases again. Therefore, it becomes less important to incentivize supplier 2 and supplier 1 would like to assign himself a higher revenue share β_1^{seq} . This positive relation between the headquarter intensity and the optimal revenue share is illustrated in the left panel of figure 7 where the black, solid line represents a high level of headquarter intensity and the black, dotted line represents a low level of headquarter intensity. For all values of the input intensity the black, dotted line runs below the black, solid line.

The second difference concerns the critical input intensity η_1^c at which a change in the sign of the derivation of β_1^{seq} with respect to ρ arises. This derivation is given by

$$\frac{\partial \beta_1^{seq}}{\partial \rho} \begin{cases} < 0, & \text{if } \eta_1 \text{ is small} \\ > 0, & \text{if } \eta_1 \text{ is high.} \end{cases} \quad (56)$$

With simultaneous production, the critical input intensity η_1^c was clearly equal to $1/2$. With sequential production, η_1^c is no longer constant. Instead, it increases in ρ . Additionally, η_1^c varies with η_H : For low values of ρ a rise of η_H decreases η_1^c and for high values of η_H a rise of η_H first increases η_1^c and then decreases it. This change in the critical input intensity can be seen in the right panel of figure 7 where the black, solid line that represents a high level of ρ runs for low values of the input intensity below the black, dotted line that represents a low level of ρ and vice versa for high values of the input intensity. The intersection is strictly lower than $1/2$.

These depicted differences lead to changes in the predictions with respect to the organizational decision:

- ii. A higher headquarter intensity makes integration more likely.
- iii. If η_1 is low, a rise of ρ makes integration more likely, and if η_1 is high, a rise of ρ makes outsourcing more likely.

Figure 8 illustrates the resulting organizational decision of supplier 1 under the assumption of symmetric revenue shares. The black, dashed line represents low values of the headquarter intensity while the black, solid line stands for high values of the headquarter-intensity. Following the predictions, we can state the following proposition:

PROPOSITION 4 *With sequential production, the cutoff input intensity η_1^{cf} which induces a change in supplier 1's organizational decision varies even with symmetric revenue shares with the level of η_H*

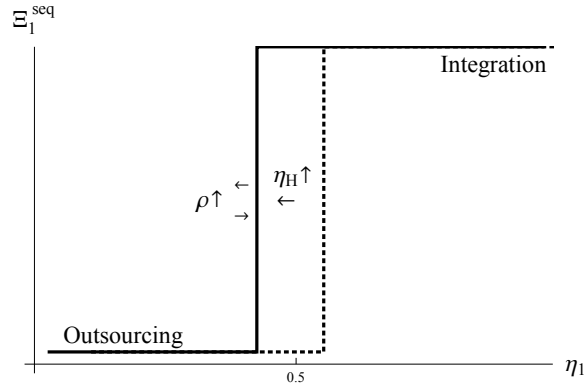


Figure 8: Organizational decision of supplier 1 subject to a variation of η_1 .
Black, dotted line: low values of η_H . Black, solid line: high values of η_H .

and ρ :

- i. The higher is η_H , the more prevalent becomes integration, i.e. the lower is η_1^{cf} .
- ii. A higher ρ first increases the prevalence of integration and then decreases it. In other words, η_1^{cf} first decreases with ρ and subsequently increases with ρ .

The Producer's Organizational Decision With sequential production, the producer chooses the organizational form that maximizes her profit

$$\begin{aligned}
\max_{\beta_H} \pi_H^{seq} &= \left[1 - \rho \left[(1 - \beta_H) (1 - \eta_H) \left[\beta_1 \eta_1 + \frac{(1 - \beta_1) (1 - \eta_1)}{\phi} \right] + \beta_H \eta_H \right] \right] R^{seq} - w_1 - w_2 \\
&= \left[1 - \rho \left[(1 - \beta_H) (1 - \eta_H) \left[\beta_1 \eta_1 + \frac{(1 - \beta_1) (1 - \eta_1)}{\phi} \right] + \beta_H \eta_H \right] \right] \\
&A \left[\rho \theta_H \left(\frac{\beta_H}{c_H} \right)^{\eta_H} \left(\theta_1 (1 - \beta_H) \left(\frac{\beta_1}{c_1} \right)^{\eta_1} \left(\frac{1 - \beta_1}{c_2 \phi} \right)^{1 - \eta_1} \right)^{1 - \eta_H} \right]^{\frac{\rho}{1 - \rho}} - w_1 - w_2.
\end{aligned} \tag{57}$$

The optimal revenue share β_H^{seq} is given as

$$\begin{aligned}
\beta_H^{seq} &= \beta_H^{seq}(\rho, \beta_1, \eta_1, \eta_H) \\
&= \frac{\eta_H (2 - \eta_1 + \rho (1 - \phi) (1 - \eta_H) - \rho (3 - \eta_1 - \eta_H)) + \beta_1 (1 - \eta_H) (1 + \rho \eta_H) (1 - \eta_1 (1 + \phi)) + b_H^{seq}}{2 (\eta_H (2 - \rho \eta_H) + (1 - \eta_H) (\eta_1 (1 - \rho \eta_H) + \beta_1 (1 - \eta_1 (2 - \rho (1 + \phi)))) - 1)} \\
\text{with } b_H^{seq} &= \eta_1 (1 - \rho) - \sqrt{(1 - \eta_H) (1 - \rho \eta_H)} \sqrt{\eta_H (1 - \rho \eta_H) (4 - \rho (4 - \rho (1 - \eta_H) \eta_H))} \\
&+ (1 - \eta_H) \left((1 - \rho \eta_H) \left(\eta_1^2 (1 - \rho (1 - \eta_H))^2 + \beta_1^2 (1 - \eta_1 (1 + \phi))^2 \right) - 2 \rho \eta_1 \eta_H (3 - \rho (3 - \rho (1 - \eta_H) \eta_H)) \right. \\
&\quad \left. + 2 \beta_1 (1 - \eta_1 (1 + \phi) (\rho \eta_H (1 - \rho \eta_H) + \eta_1 (1 - \rho (1 + \rho (1 - \eta_H) \eta_H)))) \right).
\end{aligned} \tag{58}$$

In figure 9, we illustrate this optimal revenue share with respect to η_H for different values of η_1 and ρ whereby the gray, solid line indicates again the revenue share in case of outsourcing and the gray, dashed line depicts the revenue share in case of integration.

As for supplier 1's organizational decision, there arise two differences compared to the scenario of simultaneous production: First, in contrast to the scenario of simultaneous production, the direction of the effect of η_1 on β_H^{seq} no longer solely depends on the level of η_1 , instead it is also varies with the

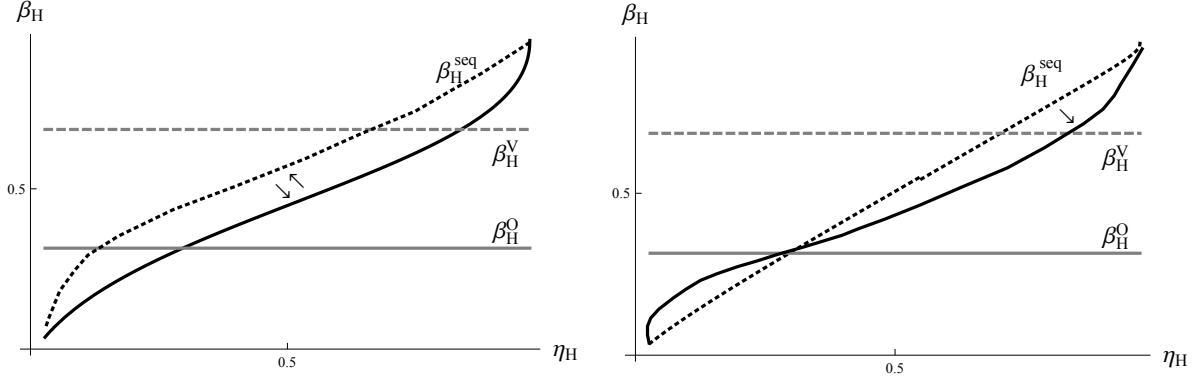


Figure 9: Optimal revenue share β_H^{seq} subject to a variation of η_H .

Left panel: low values of ρ . Black, dotted line: low or high values of η_1 . Black, solid line: intermediate values of η_1 .

Right panel: high values of ρ . Black, dotted line: low values of η_1 . Black, solid line: high values of η_1 .

level of η_H and ρ . For low values of ρ holds

$$\frac{\partial \beta_H^{seq}}{\partial \eta_1} \begin{cases} < 0, & \text{if } \eta_1 \text{ is small} \\ > 0, & \text{if } \eta_1 \text{ is high,} \end{cases} \quad (59)$$

whereas for high values of ρ holds

$$\frac{\partial \beta_H^{seq}}{\partial \eta_1} \begin{cases} > 0, & \text{if } \eta_H \text{ is small} \\ < 0, & \text{if } \eta_H \text{ is high.} \end{cases} \quad (60)$$

If ρ is low, we find the same relation as with simultaneous production: For low values of η_1 , a rise of η_1 raises the producer's optimal revenue share and for high values of η_1 , an increase of η_1 reduces this share. However, since the critical input intensity η_1^c which induces the change in the sign of the derivation is the cutoff input intensity η_1^{cf} that induces the change in supplier 2's organizational form and since with sequential production supplier 1's organizational decision on supplier 2 varies with η_H and ρ , η_1^c is no longer equal to $1/2$. More precisely, for these low values of ρ , η_1^c decreases in ρ . This change in the sign of the above derivation arises first for high values of η_H . This relation can be seen in the left panel of figure 9. The black, solid line depicts the producer's optimal revenue share for intermediate values of η_1 while the black, dotted line depicts this revenue share for low or high values of η_1 . As in the scenario of simultaneous production, the black, dotted line runs for all values of the headquarter intensity above the black, solid line. A higher η_1 first leads to a convergence of the black, dotted line to the black, solid line, and then to a divergence.

However, if ρ is sufficiently high, the sign of the derivation depends on the level of η_H : If η_H is low, an increase of η_1 raises β_H^{seq} , and if η_H is high, an increase of η_1 lowers β_H^{seq} . The critical value of η_H^c for which there is a change in the sign of the derivation depends negatively on η_1 . For medium values of η_1 , there is a jump in the critical headquarter intensity. This jump arises for the value of η_1 at which a change in supplier 1's organizational decision (from outsourcing to integration) occurs. This is illustrated in the right panel of figure 9. The black, dotted line stands for low values of η_1 whereas the black, solid line stands for high values of η_1 . For low values of η_H , the black, solid line runs above the black, dotted line and for high values of η_H , the black, solid line runs below the black, dotted line.

The second difference arises for the derivation of β_H^{seq} with respect to ρ :

$$\frac{\partial \beta_H^{seq}}{\partial \rho} \begin{cases} < 0, & \text{if } \eta_H \text{ is small} \\ > 0, & \text{if } \eta_H \text{ is high.} \end{cases} \quad (61)$$

Contrary to the scenario of simultaneous production, the critical value of headquarter intensity η_H^c which induces the change in the sign of the derivation varies not only with the level of η_1 but also with the level of ρ . With simultaneous production, for $\eta_1 < 1/2$ ($\eta_1 > 1/2$) a rise of η_1 decreased (increased) η_H^c . However, since the organizational decision of supplier 1 does no longer change at $\eta_1 = 1/2$, the direction of the effect of η_1 on η_H^c does not change there either. Instead, a higher ρ rises the cutoff η_H^c . The basic relation is depicted in figure 10 where the black, dotted line represents low values of ρ and the black, solid line represents high values of ρ . For low values of η_H , the black, solid line runs below the black, dotted line whereas for high values of η_H , the black, solid line runs above the black, dotted line.

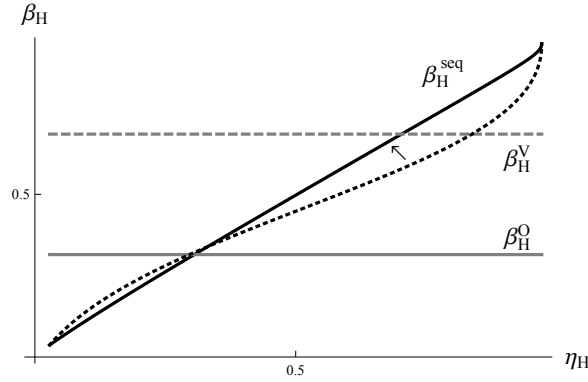


Figure 10: Optimal revenue share β_H^{seq} subject to a variation of η_H .
Black, dotted line: low values of ρ . Black, solid line: high values of ρ .

As a result, the producer's organizational decision depends as in the scenario of simultaneous production not only on η_H but also on ρ and η_1 (see figure 11).

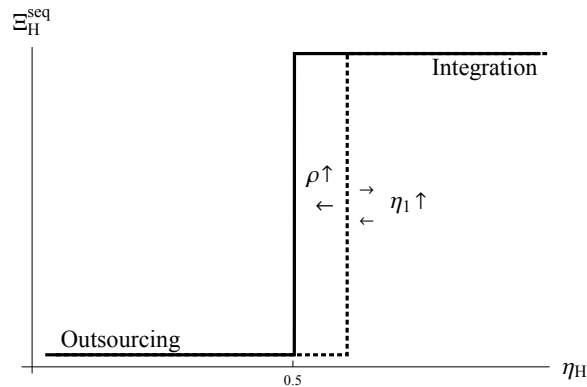


Figure 11: Organizational decision of the producer Ξ_H^{seq} subject to a variation of η_H .
Black, dotted line: low values of ρ . Black, solid line: high values of ρ .

For low values of the headquarter intensity, outsourcing is profit-maximizing for the producer and for high values of the headquarter intensity integration is profit-maximizing. As in the scenario of

simultaneous production an increase of ρ raises the likeliness of integration.¹⁶ However, for low values of ρ , a rise of η_1 first raises and then decreases the likeliness of outsourcing. If ρ is high, there is only a positive effect of η_1 on the likeliness of outsourcing.¹⁷ This can be summarized in the following proposition:

PROPOSITION 5 *With sequential production and symmetric revenue shares, the effect of η_1 on the critical input intensity η_H^{cf} which induces a change in the producer's organizational decision depends on the level of ρ : If ρ is low, a rise of η_1 first makes outsourcing more likely and then makes integration more likely. If ρ is high, a higher η_1 always makes outsourcing more likely.*

Interrelation of the producer's and supplier 1's organizational decisions Figure 12 combines the resulting organizational decisions of the producer and supplier 1. The left panel depicts these organizational decisions for the scenario of simultaneous production and the right panel depicts them for the scenario of sequential production. With sequential production there arise - as with simultaneous production - all four organizational forms ($\{O, O\}$, $\{O, V\}$, $\{V, O\}$ and $\{V, V\}$).

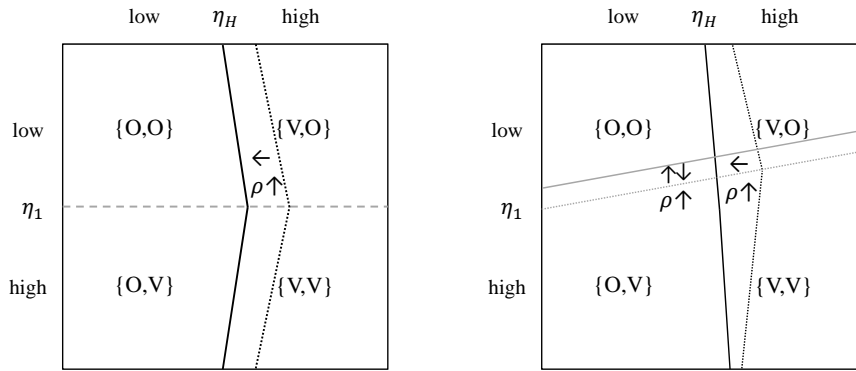


Figure 12: Organizational decisions of the producer and supplier 1.

Left panel: simultaneous production. Right panel: sequential production.

Black, dotted line: low values of ρ . Black, solid line: high values of ρ .

Gray, dashed line: all values of ρ . Gray, dotted line: low and high values of ρ . Gray, solid line: intermediate values of ρ .

As depicted in the right panel, the producer's decision is still driven by η_H , η_1 and ρ : When η_H is to the left (right) of the black, solid line or the black, dotted line, respectively, the producer chooses outsourcing (integration) of supplier 1. The higher is ρ , the more is the separating line of the headquarter intensity shifted to the left, i.e., the more likely is integration. This separating line is for low values of ρ represented by the black, dotted line and for high values of ρ , it is represented by the black, solid line. For low values of ρ , it varies with the input intensity: A higher input intensity first tilts the black, dotted line to the right and then it is tilted back to the left. However, contrary to our findings in the simultaneous scenario, the black, solid line is always tilted to the right when the input intensity increases - independent of the level of η_1 . This shows that for high values of ρ , a rise of the input intensity makes outsourcing more likely.

When η_1 is above (below) the gray, solid line or the gray, dotted line, respectively, supplier 1 chooses outsourcing (integration) of supplier 2. In contrast to the scenario of simultaneous production, the

¹⁶ As with simultaneous production, this is due to the level of η_H^c .

¹⁷ Analogously to the scenario of simultaneous production, we could also determine the organizational decisions of the producer and supplier 1 by comparing the profits in case of outsourcing and in case of integration.

separating line of the input intensity varies with the level of ρ and η_H . The gray, solid line stands for intermediate values of ρ and runs above the gray, dotted line that stands for low and high values of ρ . This shows that a rise of ρ first makes integration and then outsourcing more likely. In addition, both lines are rotated upwards with an increase of the headquarter intensity such that integration is more likely. As a result, supplier 1's organizational decision is no longer independent from the producer's organizational decision when production takes place sequentially. Instead holds:

PROPOSITION 6 *With sequential production, the organizational decisions of supplier 1 is interrelated to the producer's organizational decision.*

Comparing our sequential results with those of Antràs and Chor (2013), we find that similarly to their model, with sequential production a higher headquarter intensity increases the likeliness of integration in *all* stages. With sequential production, the decision of supplier 1 is interrelated to the producer's decision and a rise of η_H makes integration in both the upstream stage and the downstream stage more likely. However, as in the scenario of simultaneous production an increase of ρ has a different impact on the organizational decisions in our model than in the model of Antràs and Chor (2013): In the downstream stage, a higher ρ furthermore increases the likeliness of integration. In the upstream stage, a rise of ρ first increases the likeliness of integration. Only when ρ further increases, we observe an decrease of the likeliness of integration, as in Antràs and Chor (2013). However, our results are again in line with the additional effect of ρ , i.e. with the change from sequential substitutes to sequential complements that predicts a switch from outsourcing to integration in the downstream stage and a switch from integration to outsourcing in the upstream stage. More precisely, in our model holds: The higher is ρ , the more likely becomes integration in the downstream stage and, if ρ is high enough, the more likely becomes outsourcing in the upstream stage.

5 Conclusion

In our paper, we analyze organizational decisions in multistage production processes. Since the model of Antràs and Chor (2013) only explains the organizational decisions of those firms that bargain with all their suppliers and since their model is difficult to test empirically, we provide an alternative mechanism to explain these decisions. We extend the baseline model of Antràs and Helpman (2004) and assume that the manufacturing component provided by the firm's (direct) supplier 1 is itself composed of two inputs such that supplier 1 has to subcontract an own supplier 2. In contrast to Antràs and Chor (2013), the firm decides only on the organizational form of supplier 1. Supplier 1 decides himself on the organizational form of supplier 2.

After analyzing the production process in a benchmark scenario of complete contracts, we assume contracts to be incomplete. We start with a scenario of simultaneous production where all players invest at the same time. Since contracts are incomplete, the player's input provisions, revenue and profit are lower and the price is higher compared to complete contracts. Both the producer and supplier 1 choose outsourcing of their respective supplier when this supplier is relatively more important for the production, i.e., when the headquarter intensity or input intensity, respectively, is low. In contrast, when the respective supplier is relatively less important, i.e., when the headquarter intensity or input intensity, respectively, is high, the producer and supplier 1 choose integration of the respective supplier. With symmetric revenue shares, the decision of supplier 1 whether to integrate or to outsource his supplier depends solely on this input intensity and is thus independent from the producer's decision. However, the producer's decision is additionally driven by the level of the input intensity and the elasticity of demand. We then consider production to take place sequentially, i.e., we assume that supplier 2 invests previous to the producer and supplier 1. Solving by backward induction, supplier 2 anticipates the producer's and supplier 1's investment such that the players' investments are sequential complements. As a result, the underinvestment problem induced by incomplete contracts is reduced. In addition, due to the anticipation, the decision of supplier 1 is no longer independent from the producer's decision. In contrast, a higher headquarter intensity of production now increases the likeliness of integration of supplier 2. Thus, with sequentiality of production processes the organizational decisions of the producer and supplier 1 are interrelated.

These findings differ from the results of the model by Antràs and Chor (2013): On the one hand, in their model, investments cannot only be sequential complements but as well sequential substitutes. On the other hand, when investments are sequential complements, the firm chooses outsourcing of the downstream stages (and vertical integration of the upstream stages). However, since in our model sequentiality of production processes generates four organizational decisions ($\{O, O\}$, $\{O, V\}$, $\{V, O\}$ and $\{V, V\}$), we can also derive the organizational decisions of Antràs and Chor (2013), namely $\{V, O\}$ or $\{O, V\}$, respectively. These organizational decisions depend not only on the elasticity of demand but as well on two other, directly observable factors - the headquarter intensity and the input intensity of production. Thus, with our mechanism to explain organizational decisions in multistage production processes where the players' investments are always sequential complements we can nevertheless derive the same organizational decisions, however, determined by other, directly observable parameters.

In our model, there are several aspects left for future research: First of all, we consider a production process with only two suppliers. An obvious extension would be to incorporate a continuum of suppliers to analyze the interdependencies along the whole production chain. In addition, it would be interesting to test our predictions considering the organizational decisions empirically.

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Appendix

A.1 Complete Contracts - Producer Contracts with Both Suppliers

When the producer bargains with both suppliers, the production process can be modeled as a 4-stage game with the following timing of events (as in Antràs and Chor (2013)):

1. The firm offers contracts to potential suppliers of the two inputs 1 and 2. These contracts stipulate the respective supplier's input provision m_i ($i = 1, 2$) and comprise the (ex post) payment to the respective supplier s_i , and an up-front participation fee τ_i from the respective supplier that might be positive or negative.
2. There is a huge mass of potential suppliers. Each of these suppliers has an outside option equal to w_i . The suppliers apply for the contract and the producer chooses one supplier for the production of each input.
3. The headquarter and supplier 1 and 2 produce their inputs h , m_1 and m_2 , respectively.
4. The final good is produced. Revenue is realized and each player receives the payment stipulated in the contracts.

Solving by backward induction, each player receives the payment specified in the respective contract, i.e., supplier 1 receives the payment s_1 and supplier 2 receives the payment s_2 while the producer retains the residual $(R - s_1 - s_2)$ in stage 4.

Since contracts are complete, the producer and the two suppliers produce their inputs in stage 3 in the amounts h , m_1 and m_2 , respectively, that are stipulated in the contracts.

In stage 2, the suppliers only accept the producer's contract offer when the respective supplier's profit π_i ($i = 1, 2$) is at least equal to the respective supplier's outside option w_i :

$$\pi_i = (s_i - \tau_i) - c_i m_i \geq w_i. \quad (62)$$

The producer sets the net payment to the respective supplier i ($s_i - \tau_i$) such that his profit exactly equals his outside option: $s_i - \tau_i = c_i m_i + w_i$. Hence, as in the scenario of complete contracts in the main section, each supplier's net payment is equal to his production costs plus his outside option.

In stage 1 where the producer decides on the contract design, she chooses the input provisions h , m_1 and m_2 that maximize her own profit:

$$\max_{\{h, m_1, m_2\}} \pi_H = R - c_H h - (s_1 - \tau_1) - (s_2 - \tau_2). \quad (63)$$

Considering the suppliers' participation constraint gives:

$$\max_{\{h, m_1, m_2\}} \pi_H = R - c_H h - c_1 m_1 - c_2 m_2 - w_1 - w_2. \quad (64)$$

Differentiating this profit with respect to h , m_1 and m_2 and solving for h , m_1 and m_2 gives the profit-maximizing input provisions:

$$h^{cc} = \frac{\rho \eta_H}{c_H} R^{cc}, \quad m_1^{cc} = \frac{\rho \eta_1 (1 - \eta_H)}{c_1} R^{cc} \quad \text{and} \quad m_2^{cc} = \frac{\rho (1 - \eta_1) (1 - \eta_H)}{c_2} R^{cc} \quad (65)$$

$$\text{with } R^{cc} = A \left[\frac{\rho \theta_H}{c_H^{\eta_H} c_M^{1-\eta_H}} \right]^{\frac{\rho}{1-\rho}} = A \left[\frac{\rho \theta_H \theta_1^{1-\eta_H}}{c_H^{\eta_H} (c_1^{\eta_1} c_2^{1-\eta_1})^{1-\eta_H}} \right]^{\frac{\rho}{1-\rho}}.$$

These input provisions are equal to those in the scenario of complete contracts in the main section.

As in the main section, both suppliers' profits are zero. The producer's profit is still given by

$$\pi_H^{cc} = (1 - \rho) R^{cc} - w_1 - w_2 \quad (66)$$

and the price is still

$$p^{cc} = \frac{c_H^{\eta_H}}{\rho \theta_H} \left(\frac{c_1^{\eta_1} c_2^{1-\eta_1}}{\theta_1} \right)^{1-\eta_H}. \quad (67)$$

A.2 Simultaneous Production: Concrete Derivatives of β_1^{sim}

Derivation with respect to η_1 :

$$\frac{\partial \beta_1^{sim}}{\partial \eta_1} = \frac{1}{\underbrace{(1 - 2\eta_1)^2 (1 - \rho \eta_H)}} \cdot d_{1,\eta_1}^{sim} \quad \text{with}$$

$$> 0$$

$$d_{1,\eta_1}^{sim} = (1 - \rho (1 - 2(1 - \eta_1) \eta_1) (1 - \eta_H)).$$

$$\left(\frac{1 - 2\rho (1 - \eta_1) \eta_1 (1 - \eta_H)}{\sqrt{(2\eta_1 (1 - \rho ((1 - \eta_H) (1 - \eta_1) + \eta_H)) + \rho \eta_H)^2 + 4\eta_1 (1 - 2\eta_1) (1 - \rho \eta_H) (1 - \rho (1 - \eta_1) (1 - \eta_H))}} - 1 \right) > 0$$

Simple maths shows that d_{1,η_1}^{sim} is for $0 < \eta_1 < 1$, $0 < \eta_H < 1$ and $0 < \rho < 1$ positive. As a result, the derivation of β_1^{sim} with respect to η_1 is for these values positive.

Derivation with respect to η_H :

$$\frac{\partial \beta_1^{sim}}{\partial \eta_H} = \frac{1}{\underbrace{2(1 - \rho \eta_H)^2}_{> 0} \underbrace{(1 - 2\eta_1)}_{?}} \cdot d_{1,\eta_H}^{sim} \quad \text{with}$$

$$d_{1,\eta_H}^{sim} = \rho \left(\frac{2(1 - \eta_1) \eta_1 (3 - 2\rho (1 + (1 - \rho) (1 - \eta_1) \eta_1)) + \rho (1 - 2(1 - \eta_1) \eta_1 (1 - 2(1 - \rho) (1 - \eta_1) \eta_1)) \eta_H}{\sqrt{(2\eta_1 (1 - \rho ((1 - \eta_H) (1 - \eta_1) + \eta_H)) + \rho \eta_H)^2 + 4\eta_1 (1 - 2\eta_1) (1 - \rho \eta_H) (1 - \rho (1 - \eta_1) (1 - \eta_H))}} - 1 - 2\eta_1 (1 - \rho) (1 - \eta_1) \right) < 0$$

Simple maths shows that d_{1,η_H}^{sim} is for $0 < \eta_1 < 1$, $0 < \eta_H < 1$ and $0 < \rho < 1$ negative. The sign of the derivation of β_1^{sim} with respect to η_H depends on the sign of $(1 - 2\eta_1)$ and thus on the level of η_1 . For $\eta_1 < 1/2$, $(1 - 2\eta_1)$ is positive and the derivation is negative. For $\eta_1 > 1/2$, $(1 - 2\eta_1)$ is negative. As a result, the derivation is positive.

Derivation with respect to ρ :

$$\frac{\partial \beta_1^{sim}}{\partial \rho} = \frac{1}{\underbrace{2(1-\rho\eta_H)^2}_{>0} \underbrace{(1-2\eta_1)}_{?}} \cdot d_{1,\rho}^{sim} \quad \text{with}$$

$$d_{1,\rho}^{sim} = \frac{2(1-\eta_1)\eta_1 \left(3\eta_H - \rho \left(\eta_H^2 + \eta_H - 2\eta_1(1-\eta_1)(1-\eta_H)^2 \right) - 1 \right) + \rho\eta_H^2}{\sqrt{(2\eta_1(1-\rho((1-\eta_H)(1-\eta_1)+\eta_H)) + \rho\eta_H)^2 + 4\eta_1(1-2\eta_1)(1-\rho\eta_H)(1-\rho(1-\eta_1)(1-\eta_H))}} + 2(1-\eta_1)\eta_1(1-\eta_H) - \eta_H < 0$$

For $0 < \eta_1 < 1$, $0 < \eta_H < 1$ and $0 < \rho < 1$ $d_{1,\rho}^{sim}$ is negative. The sign of the derivation of β_1^{sim} with respect to η_H depends on the sign of $(1-2\eta_1)$ and thus on the level of η_1 . For $\eta_1 < 1/2$, $(1-2\eta_1)$ is positive and the derivation is negative. For $\eta_1 > 1/2$, $(1-2\eta_1)$ is negative. As a result, the derivation is positive.

A.3 Simultaneous Production: Organizational Decision of Supplier 1

An alternative approach to determine supplier 1's profit-maximizing organizational decision is to compare the profits in case of outsourcing with those in case of integration. Supplier 1's maximization problem is given by

$$\max_{\{\beta_1^O, \beta_1^V\}} \pi_1^{sim} = \max \{ \pi_1^{sim}(\beta_1 = \beta_1^O), \pi_1^{sim}(\beta_1 = \beta_1^V) \} = \max \{ \pi_1^{simO}, \pi_1^{simV} \}. \quad (68)$$

Reformulating the problem, supplier 1 chooses integration of supplier 2 if $\pi_1^{simrel} = \pi_1^{simV} / \pi_1^{simO} > 1$ and supplier 1 chooses outsourcing of supplier 2 if $\pi_1^{simrel} = \pi_1^{simV} / \pi_1^{simO} < 1$. Using equation (23), the relative profit of integration is given by

$$\pi_1^{simrel} = \left[\frac{c_2^{O^{1-\eta_1}} \beta_1^{V\eta_1} (1-\beta_1^V)^{1-\eta_1}}{c_2^{V^{1-\eta_1}} \beta_1^{O\eta_1} (1-\beta_1^O)^{1-\eta_1}} \right]^{\frac{\rho(1-\eta_H)}{1-\rho}} \frac{1-\rho \left([(1-\beta_1^V)(1-\eta_1) + \beta_1^V\eta_1] [1-\eta_H] \right)}{1-\rho \left([(1-\beta_1^O)(1-\eta_1) + \beta_1^O\eta_1] [1-\eta_H] \right)}. \quad (69)$$

The first term, i.e., the term within the brackets, is independent from ρ and η_H , only the second term varies with respect to η_H and ρ . However, as long as β_1^O and β_1^V are equally distributed around 1/2 ($\beta_1^V = (1-\beta_1^O)$) this relative profit is smaller than 1 if $\eta_1 < 1/2$ and larger than 1 if $\eta_1 > 1/2$ - independent of the values of ρ and η_H . Hence, for $\eta_1 < 1/2$ outsourcing is profit-maximizing and for $\eta_1 > 1/2$ integration. The results of this approach are thus identical to those of the approach based on the optimal revenue share β_1^{sim} .

A.4 Simultaneous Production: Concrete Derivatives of β_H^{sim}

Derivation with respect to η_H :

$$\frac{\partial \beta_H^{sim}}{\partial \eta_H} = \frac{1}{\underbrace{2(\eta_H - (1-\beta_1(1-2\eta_1) - \eta_1)(1-\eta_H))^2}_{>0}} \cdot d_{H,\eta_H}^{sim} \quad \text{with}$$

$$d_{H,\eta_H}^{sim} = \dots > 0$$

Since d_{H,η_H}^{sim} is always positive, the derivation is positive as well.

Derivation with respect to η_1 :

$$\frac{\partial \beta_H^{sim}}{\partial \eta_1} = \overbrace{(1 - 2\beta_1)}^{?} \cdot \overbrace{\frac{(1 - \eta_H)(1 - \rho\eta_H)}{2((1 - \eta_1 + \beta_1(-1 + 2\eta_1))(-1 + \eta_H) + \eta_H)^2}}^{> 0} \cdot d_{H,\eta_1}^{sim} \quad \text{with}$$

$$d_{H,\eta_1}^{sim} = \left(\frac{\sqrt{1 - \eta_H}(\eta_1 + (2 - \rho)(2 - \eta_1)\eta_H + \beta_1(1 - 2\eta_1)(1 - (2 - \rho)\eta_H))}{\sqrt{4(1 - \rho)\eta_H + (1 - \eta_H)(\eta_1 + \rho(2 - \eta_1)\eta_H + \beta_1(1 - 2\eta_1)(1 - \rho\eta_H))^2}} \right) - 1 < 0$$

Since simple maths shows that d_{H,η_1}^{sim} is always negative, the sign of the derivation of the producer's optimal revenue depends on the sign of $(1 - 2\beta_1)$: For $\beta_1 < 1/2$, i.e. for $\eta_1 < 1/2$,¹⁸ this term is positive and the derivation is thus negative. Vice versa, if $\beta_1 > 1/2$, i.e. if $\eta_1 > 1/2$, the term is negative and the derivation is positive.

Derivation with respect to ρ :

$$\frac{\partial \beta_H^{sim}}{\partial \rho} = \frac{\overbrace{\eta_H}^{> 0} \cdot d_{H,\rho}^{sim}}{\underbrace{2(\eta_H - ((1 - \eta_1)(1 - \beta_1) + \beta_1\eta_1)(1 - \eta_H))}_{?}} \quad \text{with}$$

$$d_{H,\rho}^{sim} = \sqrt{(1 - \eta_H)} \cdot \frac{2 - (1 + \beta_1\eta_1 + (1 - \beta_1)(1 - \eta_1))(1 - \eta_H)(\eta_1 + \rho(2 - \eta_1)\eta_H + \beta_1(1 - 2\eta_1)(1 - \rho\eta_H))}{\sqrt{(4(1 - \rho)\eta_H + (1 - \eta_H)(\eta_1 + \rho(2 - \eta_1)\eta_H + \beta_1(1 - 2\eta_1)(1 - \rho\eta_H))^2)}} - (1 + \beta_1\eta_1 + (1 - \beta_1)(1 - \eta_1))(1 - \eta_H) > 0$$

Simple maths shows that $d_{H,\rho}^{sim}$ is always positive. Thus, the sign of the derivation depends on the sign of the denominator. For low (high) values of η_H , the denominator is negative (positive) such that the derivation is negative (positive). We can calculate the level of the cutoff headquarter intensity η_H^c at which the sign of the denominator changes; it is given by

$$\eta_H^c = 1 - \frac{1}{\underbrace{1 + \beta_1\eta_1 + (1 - \beta_1)(1 - \eta_1)}_{> 1}} < 1$$

¹⁸ Note that this clear threshold of η_1 is due to our assumption of symmetric revenue shares $\beta_1^O = (1 - \beta_1^V)$ in the main text.

$$\text{with } \frac{\partial \eta_H^c}{\partial \eta_1} = - \frac{\overbrace{1 - 2\beta_1}^?}{\underbrace{(1 + \beta_1 \eta_1 + (1 - \beta_1)(1 - \eta_1))^2}_{> 0}}.$$

As the derivation of the cutoff headquarter intensity with respect to η_1 depicts, the cutoff headquarter intensity varies with the level of β_1 (and thus η_1). If $\beta_1 < 1/2$, i.e. if $\eta_1 < 1/2$, the derivation is negative and the cutoff headquarter intensity rises with η_1 . Vice versa, if $\beta_1 > 1/2$, i.e. if $\eta_1 > 1/2$, the derivation is positive and η_H^c increases in η_1 .

A.5 Simultaneous Production: Organizational Decision of the Producer

To determine the producer's profit-maximizing organizational decision, we can alternatively compare the producer's profits in case of outsourcing with the profits in case of integration. This gives the following problem:

$$\max_{\{\beta_H^O, \beta_H^V\}} \pi_H = \max \{ \pi_H (\beta_H = \beta_H^O), \pi_H (\beta_H = \beta_H^V) \} = \max \{ \pi_H^O, \pi_H^V \}. \quad (70)$$

This problem can be depicted in terms of relative profits: If $\pi_H^{rel} = \pi_H^V / \pi_H^O > 1$, the producer chooses integration of supplier 1, and if $\pi_H^{rel} = \pi_H^V / \pi_H^O < 1$, the producer chooses outsourcing of supplier 1. This relative profit is equal to

$$\pi_H^{rel} = \left[\frac{c_1^O \eta_1^{(1-\eta_H)} \beta_H^V \eta_H (1 - \beta_H^V)^{1-\eta_H}}{c_1^V \eta_1^{(1-\eta_H)} \beta_H^O \eta_H (1 - \beta_H^O)^{1-\eta_H}} \right]^{\frac{\rho}{1-\rho}} \frac{1 - \rho [(1 - \beta_H^V)(1 - \eta_H) [(1 - \beta_1)(1 - \eta_1) + \beta_1 \eta_1] + \beta_H^V \eta_H]}{1 - \rho [(1 - \beta_H^O)(1 - \eta_H) [(1 - \beta_1)(1 - \eta_1) + \beta_1 \eta_1] + \beta_H^O \eta_H]}. \quad (71)$$

Both terms depend not only on η_H but also on ρ and η_1 . The relative profit is for low values of η_H smaller than 1 and for high values of η_H larger than 1. Hence, for small values of η_H outsourcing is profit-maximizing and for high values of η_H integration. The cutoff-level of η_H for which the organizational decision changes depends on the level of ρ and η_1 . As for supplier 1's decision, the resulting organizational decisions are thus identical to those of the approach based on the optimal revenue share β_H^{sim} .

A.6 Sequential Production: Concrete Derivatives of β_1^{seq}

To be written.

A.7 Sequential Production: Concrete Derivatives of β_H^{seq}

To be written.