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The Whole Is Greater than the Sum of Its Parts - Pricing Pressure Indices for Mergers of Vertically Integrated Firms*

Michael Trost†

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Abstract

The paper analyzes gross upward pricing pressure indices called `iGUPPI` to assess the effects of a merger between vertically integrated firms where in the downstream market also independent rivals are active. Such indices could be used e.g. to screen mergers between mobile network operators which compete with mobile virtual network operators in the downstream retail market. It is shown that the `iGUPPI` for the downstream market corresponds to the sum of two well-known upward pricing pressure indices, the `GUPPI` concept of Salop/Moresi (2009) and the `vGUPPI` concept of Moresi/Salop (2013). Such a simple decomposition however does not hold for the upstream market a priori. Here, additional effects arise which are not included by the two concepts. Further assumptions on the price reactions of the downstream divisions to increases in the input prices are imposed so that the `iGUPPI` for the upstream market allows for a decomposition into an upstream market version of the `GUPPI` and the `vGUPPI`.

JEL–Classifications: L41, L42

Keywords: Pricing pressure indices, vertically integrated firms, mergers, UPP, GUPPI, vGUPPI

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1 Introduction

During the last two decades, competition authorities have made a fundamental shift in their approach to evaluating mergers in markets with differentiated products where firms compete with prices. In the past, merger effects were assessed almost exclusively by market shares and the change in market shares caused by the merger. This approach requires the definition of the relevant market. The standard procedure to identify a market is the so-called SSNIP test.[1] In markets with differentiated products however, this approach usually proves to be problematic for at least three reasons: First, if there are no gaps in the chain of substitution, procedures like the SSNIP test tend to define markets too broadly thus generating small market shares and underestimating market power. Second, market definition classifies products as either "in the market" or "out of the market" which implies that all products in the relevant market are perfect substitutes while products not in the relevant market impose no competitive constraints at all on the products in the relevant market. In the case of differentiated products however, the intensity of competition is far more important – a merger of firms whose products are close substitutes will usually have very different effects on the market outcome as compared with a merger of two firms producing distant substitutes even if the markets shares are the same in both cases. Finally, this approach is based on the premise that there exists a positive relationship between market concentration and market power. However, it might be questionable whether such a relationship holds for markets with differentiated products.

In view of these difficulties, two alternative approaches to assessing mergers have been taken on in merger analysis, merger simulation and upward pricing pressure measures. Merger simulation usually requires the estimation of a complex demand system. The marginal costs of the firms are recovered from this estimated demand system and specific assumptions on the mode of competition (e.g. Bertrand competition).[2] In the final stage, the recovered marginal costs and the estimated demand parameters are used to simulate the price effects of a merger. A shortcoming of this approach is that the predicted price effects are very sensitive to the specified demand system. It depends on the curvature of the demand functions how much of any efficiency gains induced by the merger are passed on to the price paid by the consumers. Moreover, there is the practical issue that in-depth merger simulations are difficult to implement in the short amount of time available for the merger review.

The upward pricing pressure approach suggested by Salop/Moresi (2009) and Farell/Shapiro (2010a) tries to assess the impact of a merger directly by considering the incentives of the merging firms to raise the price of one of its products. The intensity of this incentive is measured by the so-called gross upward pricing pressure index. Its construction is related to

[1] The Small but Significant and Non-transitory Increase in Price (SSNIP) test identifies the relevant market by determining whether a profit-maximizing hypothetical monopolist in the candidate market would raise the product prices significantly, typically by 5 to 10 percent for at least one year, above their current levels. For a survey on the different ways to define relevant markets see OECD (2012).

[2] A a comprehensive survey classifying the various approaches in merger simulation is provided in Budzinski/Ruhmer (2010) or Schwalbe/Zimmer (2009).

an idea of Werden (1996). The value of such an index gives the amount of the reduction in the marginal cost required for offsetting the incentive of a merging partner to increase the price of its product due the recapture of the other merging partner. This approach avoids some of the problems concerning the definition of the relevant market and merger simulation. In some merger cases, it turns out that upward pricing pressure indices are easier to implement than the other two approaches. Moreover, these indicies take into account the intensity of competition prevailing between the two firms before their merger by specifying the diversion ratio of their products. The diversion ratio between two products A and B indicates the fraction of product A's lost sales that would be diverted to B in case of an increase in the price of A.[3] Obviously, the higher the diversion ratio, the more intense is the competition between the two products. Finally, the problem of the demand curvature with which merger simulation is plagued is circumvented by construction since upward pricing pressure indices are calculated at the pre-merger prices.[4]

The first type of gross upward pricing pressure indices has been introduced by Salop/Moresi (2009). They analyze the standard `GUPPI` which measures the incentive of a horizontal merger between two single-product firms to increase its prices.[5] Meanwhile, these indices have been utilized by several competition authorities like the EU Commission or the Federal Trade Commission in their merger reviews. In academic literature, Baltzopoulos et. al. (2015) have applied this index to several merger cases in Sweden and Sørgard (2012) has used the index to asses the price effects of a acquisition in the Norwegian grocery market. Moreover, variants of this concept has been suggested which are applicable to other types of mergers and market conditions. Willig (2011) has extended the standard `GUPPI` to cases in which the merger causes quality changes in the products and to partial acquisitions, i.e. to cases in which a firm acquires only a partial equity stake of another firm. The adjusted gross upward pricing pressure index of Neurohr (2016) incorporates cases in which the firms are confronted with capacity constraints or kinked demand curves. Affelt et al. (2013) has derived gross upward pricing pressure indices to assess mergers of platforms. The `vGUPPI` concept of Moresi/Salop (2013) measures the incentives of vertical mergers to increase the prices of their intermediate and final products. To the best or our knowledge, however, there is one type of merger which has not yet been covered in the upward pricing pressure literature although several of such mergers has been extensively scrutinized by competition authorities in recent years. In this paper, we aim to fill this gap. Our objective is to derive gross upward pricing pressure indices called `iGUPPI` for mergers of vertically integrated firms.

In the last decade, this type of merger has occurred particularly in the telecommunication sector

[3]Market shares in a differentiated product market are an indicator of the intensity of competition only to the extent that they are proportional to the diversion ratio. This, however, holds only under the special condition that all products in the relevant market are "equally differentiated" as has been shown by Willig (1991).

[4]The commonalities and differences between merger simulation and the upward pricing pressure approach are discussed in Epstein/Rubinfeld (2010) and Farell/Shapiro (2010b).

[5]The derivation of the `GUPPI` from the profit maximization problem of the merged firm is concisely described e.g. in Baltzopoulos et. al. (2015), Moresi (2010) and Willig (2011).

when two mobile network operators (MNO) merged. Such operators have their own network infrastructure and are active on two stages of the supply chain, the provisions of network services upstream and telecommunication services downstream. In the upstream stage, they offer network access to independent mobile virtual network operators (MVNO) which have no own network infrastructure and are thus dependent on network access to supply telephone services in the downstream retail market. Here, the MVNOs compete with the MNOs who also offer retail services. Prominent examples of mergers of MNOs in Europe are: Hutchison 3G Austria/Orange Austria in 2012, Hutchsion 3G UK/Telefónica Ireland in 2014, Telefónica Deutschland/E-Plus in 2014, Hutchsion 3G UK/Telefónica UK in 2016. Our `iGUPPI` concept aims to asses the pressure induced by such merger on the upstream and downstream prices.

Interestingly, the European Commission has applied the `GUPPI` concept of Salop/Moresi (2009) on the above mentioned mergers to asses the pressure caused by the merger on the downstream retail prices.[6] The question arises whether the `GUPPI` concept is still an appropriate measure of the pricing pressure even if the merging firms operate on two stages of the supply chain. As will be shown in this paper, this might lead to an (possibly substantial) underestimation of the actual pricing pressure. The reason is that there are additional pricing pressure effects not captured by the `GUPPI` for this kind of mergers. If a merging partner A increase one of its downstream prices, then the other merging partner B profits from the recapture in the downstream market as former customers of A switch to B. This recapture constitutes the horizontal pricing pressure of the merger. The standard `GUPPI` includes this pricing pressure. However, the increase in the downstream price of A also boosts the demand of the downstream competitors of A and B. As some of them source intermediate goods from the vertically integrated firm B, the demand for these goods might increase. Firm B might thus experience also a rise of its profits in the upstream market. This recapture constitutes the vertical pricing pressure of the merger. This effect is ignored whenever the `GUPPI` concept is applied on mergers of vertically integrated firms.

In our paper, we analyze `iGUPPI`s for the upstream and downstream market prices charged by the merged firm. For this purpose, we consider a two-stage differentiated Bertrand competition game with imperfect information. Such a game has been used in Moresi/Salop (2013) for the derivation of the `vGUPPI` concept which captures the incentives to increase prices if two firms operating at different levels of a supply chain merge. According to the upward pricing pressure methodology, the reference point of our derivation is the situation pre-meger which we assume is a perfect Bayesian equilibrium of the game. It turns out that our `iGUPPI` with respect to the downstream prices corresponds to the sum of the standard `GUPPI` and the `vGUPPI`. Unfortunately, such a simple decomposition is generally not possible for our `iGUPPI` with respect to the upstream prices. The reason is that an increases in a price set by the upstream division of some merging partner triggers two price reactions in the downstream

[6] See for example EU merger case no COMP/M.7018 - Telefónica Deutschland/E-Plus, available at http://ec.europa.eu/competition/mergers/cases/additional_data/m7018_5501_3.pdf. For a discussion of the competitive effects of this merger see Maier-Rigaud/Schwalbe (2015).

market. The downstream division of this merging partner and the downstream competitor whose input has become more expensive might adjust their downstream prices to this price increase. The former price reaction is captured neither by the `GUPPI` concept nor by the `vGUPPI` concept. Nonetheless, if one assumes that this price reaction is negligible, our `iGUPPI` becomes decomposable in an upstream market variant of the `GUPPI` concept and the `vGUPPI` concept.

Presumably, the papers most similar to our paper are the ones of Ashjell et al. (2017) and Bergh et al. (2017). They study the price effects caused by a horizontal merger with vertical relations. The analysis of Bergh et al. (2017), who set up a more general market model than Ashjell et al. (2017), includes the case of a merger between two vertically integrated firms. However, the assumptions and objectives of these articles differ substantially to ours. First, the two articles assume a specific functional form, or more precisely, a linear form of the demand functions and analyze only the price effects caused by the merger in the downstream market. More importantly, the analysis of Ashjell et al. (2017) and Bergh et al. (2017) consists of comparative statics. It compares the prices pre-merger with ones post-merger. In contrast to that, our paper follows the upward pricing pressure methodology and asses the intensity of the incentives of the merged firm to increase its prices at the pre-merger level. Such an analysis does not require the specification of prices post-merger and thus becomes immune to the curvature of the demand function.[7]

The paper is organized as follows. Section two describes the framework of our analysis. In section three, the situation pre-merger is characterized as a benchmark. The situation post merger is discussed in section four. Here, the gross upward pricing pressure indices `iGUPPI` for downstream and upstream prices are also derived. In section five, these indices are transformed in a way so that they can be calculated using well-known economic concepts like diversion ratios and profit margins. Moreover, a numerical example is presented in this section in order to underscore the usefulness of our pricing pressure indices. For practitioners, it might be sufficient to read only this section. Section six concludes.

2 The Setting

Our objective is to analyze the upward pricing pressure caused by a merger of two vertically integrated firms. To accomplish this task, we consider a supply chain consisting of a upstream and a downstream market. There are two vertically integrated firms, firm 1 and firm 2, operating in both the upstream market and the downstream market. Without loss of generality, we assume that there are no further competitors in the upstream market. In other words, the two firms are the only suppliers for the firms in the downstream market. Besides the firms 1 and 2, there are several non-integrated competitors in the downstream market, manufacturers 3 to

[7] This advantage of the upward pricing pressure approach is extensively discussed in Schmalensee (2009).

M.[8] The mode of competition in both markets is that of a differentiated Bertrand competition.

Like in Moresi/Salop (2013), the price-setting process is modeled as a two-stage game. In the first stage, each supplier $i \in \{1,2\}$ chooses its input prices w_k^i charged to the non-integrated manufacturers $k \in \{3,\ldots,M\}$. Input suppliers thus might set a different input price for each downstream firm. We summarize the input prices of the supply chain by the input price vector $w := (w_3^1,\ldots,w_M^1,w_3^2,\ldots,w_M^2)$. The input prices chosen by supplier i are given by the vector $w^i := (w_1^i,\ldots,w_M^i)$ and the input prices faced by the non-integrated manufacturer k are listed by the pair $w_k := (w_k^1,w_k^2)$. In the second stage of our competition game, each manufacturer $k \in \{1,\ldots,M\}$ chooses its output price p_k. These output prices are summarized by the output price vector $p := (p_1,\ldots,p_M)$.

The two-stage game is a game of imperfect information. Each non-integrated manufacturer observes only the prices charged for its inputs. Such a manufacturer is not informed about the input prices of the other manufacturers. This lack of information entails that the information sets of a non-integrated manufacturer k are identifiable by the input price vector w_k. The manufacturer of the vertically integrated firm i knows all input prices charged by its upstream division. Therefore, it is justified to identify the information set of the manufacturer of the vertically integrated firm i by the input price vector w^i.

Concerning the costs we assume that supplier i's marginal costs might differ among the manufacturers, e.g., because the delivery of the inputs to the manufactures causes different transportation or service costs. However, supplier i's marginal costs are assumed to be constant with respect to the quantity delivered to the manufacturers. We denote henceforth by c_k^i the constant marginal cost of the input offered by supplier i to the non-integrated manufacturer k. While each non-integrated manufacturer might combine inputs from different suppliers, the downstream division of a vertically integrated firm i source all their inputs from its upstream division at the transfer price equal to the constant marginal cost c_i.

The technologies of all manufacturers exhibit constant scales of return so that the input coefficients of the cost-minimizing manufacturers are independent of the quantity produced.[9] We denote henceforth manufacturer k's production coefficient with respect to the input offered by supplier i by $S_k^i(w_k^1,w_k^2)$. This input coefficient gives the quantity of the input the non-integrated manufacturer k sources from supplier i per unit of output produced at the input prices (w_k^1,w_k^2). It is assumed that the input coefficient function $S_k^i(\cdot)$ is differentiable. Cost minimization implies that this function is non-increasing in the input price w_k^i charged by sup-

[8] The methodology behind the upward pricing pressure indices ensures that a more comprehensive market structure would not affect the formulas of our indices. To see this, it is necessary to bear in mind that the upward pricing pressure analysis is based on isolated price increases. While increasing one of the prices charged by the merged firm, the prices set by the (other) suppliers remain unchanged. For this reason, the existence of non-integrated upstream competitors does not affect the construction of the upward pricing pressure indices. Moreover, the formulas of our indices remain also unchanged if there are additional manufacturers which are upstream divisions of vertically integrated firms. As long as these vertically integrated firms source all their inputs from their upstream divisions, an increase in one of the prices set by the merged firm is not observed by them. Hence, such a price increase does not trigger price reactions of such firms.

[9] See also Proposition 5.C.2 (viii) in Mas-Colell et al. (1995).

plier i and non-decreasing increases in the input price w_k^j charged by supplier $j \neq i$.[10] If both S_k^i and S_k^j are constant and non-negative, the non-integrated manufacturer k is said to operate with a fixed input ratio. Or putting it differently, the two inputs turn out to be perfectly complementary in this case.

The demand for the product of manufacturer k at price vector p is denoted by $D_k(p_1, \ldots, p_M)$. We assume that the demand function $D_k(.)$ for product k is differentiable. Moreover, it is decreasing in its own price p_k and increasing in the price p_m of any other product $m \neq k$. Notice that the latter assumption states that the other products are (imperfect) substitutes to the product offered by manufacturer k. In mathematical terms, our assumptions on the demand functions require that $\frac{\partial D_k}{\partial p_k}(p) < 0$ and $\frac{\partial D_k}{\partial p_m}(p) > 0$ hold for any (relevant) output price vector p and any two different products k, m.

As done in Moresi/Salop (2013), our two-stage competition game is solved by the concept of perfect Bayesian equilibrium. One of its solutions is assumed to be the pre-merger situation. This situation constitutes the starting point of the forthcoming upward pricing pressure analysis of a merger between two vertically integrated firms. The intensity of the incentive of the merged firm to increase its input and output prices is evaluated at the pre-merger equilibrium price level. Optimality conditions for these prices are derived in the following section. In line with standard terminology, we term our indices `iGUPPI`. Their construction is detailed in the Sections four and five of this paper. These indices might be viewed as complementary to the known `GUPPI` and `vGUPPI` concepts which have been designed by Salop/Moresi (2009) and Moresi/Salop (2013) to measure the upward pricing pressure in the case of horizontal and vertical mergers, respectively. The interpretation of our and their indices is the same. The greater the value of such an index for some price, the stronger the incentive of the merged firm to increase this price and, thus, the more anti-competitive the merger might be.

3 The Situation Pre-Merger

The reference point of pricing pressure indices is the economic situation before the merger. To specify the upward pricing pressure induced by the merger of our two vertically integrated firms 1 and 2, it is therefore necessary to characterize their economic situation pre-merger. The situation pre-merger is assumed to be a perfect Bayesian equilibrium of the two-stage competition game we have described in the previous section. We denote henceforth by $(\hat{w}, \hat{p})$ the price vector realized at this equilibrium. The equilibrium price strategy of manufacturers k is denoted by $\hat{p}_k(.)$. Such a mapping discloses the price charged by manufacturer k at each of its information sets. We summarize henceforth these price strategies by the equilibrium price strategy profile $\hat{p}(.)$ where $\hat{p}(w) := (\hat{p}_1(w), \ldots, \hat{p}_M(w))$.[11] It gives the output prices charged

[10] See also Proposition 5.C.2 (vii) in Mas-Colell et. al. (1995).

[11] Without any loss of precision, we can write the equilibrium output price strategies of the manufactures as functions of input price vector w even if the output prices of the non-integrated manufacturers k are unaffected

by the manufactures for any input price vector w. In the subsequent paragraphs, we impose several assumptions on the equilibrium price vector and the equilibrium price strategies of the manufacturers.[12] These assumptions apply throughout the paper and are used to infer qualitative statements about our indices.

First, it is taken for granted that there is no cross subsidization at the equilibrium prices, meaning any business relationship taken up by the integrated firms proves to be profitable.[13] More precisely, we require that the equilibrium output price $\hat{p}_i$ charged by some vertically integrated firm i exceed the marginal cost c_i and any equilibrium input price $\hat{w}_k^i$ charged by this firm exceed the marginal cost c_k^i whenever its upstream division delivers inputs to manufacturer k, i.e.

$$\hat{p}_i > c_i \text{ and, if } S_m^i(\hat{w}) > 0, \text{ then } \hat{w}_m^i > c_m^i \,. \tag{1}$$

In what follows, we also assume that the price strategies of the manufactures are differentiable. In order to examine the impact of an increase in input price w_k^i on the prices charged by the manufacturers, we remark that according to the above assumptions on the manufacturers' knowledge only two manufacturers observe this price increase, the downstream division of firm i and the non-integrated manufacturer k. It is assumed that manufacturer k's price strategy is increasing in the input price w_k^i as long as manufacturer k employs inputs offered by supplier i. This assumption says that a non-integrated manufacturer passes on at least partially the increase in the price of one of its inputs to the consumers of its product. Whenever the manufacturer k does not employ inputs from the upstream division of firm i there will be no price reactions, neither from manufacturer k nor from the downstream division of firm i. Mathematically, these assumptions on the price reactions of the two firms are summarized as follows:

$$\text{if } S_k^i(w_k) > 0, \text{then } \frac{\partial \hat{p}_k}{\partial w_k^i}(w) > 0, \text{otherwise } \frac{\partial \hat{p}_k}{\partial w_k^i}(w) = \frac{\partial \hat{p}_i}{\partial w_k^i}(w) = 0 \,. \tag{2}$$

Because the other manufacturers do not observe the increase in input price w_k^i their price setting is unaffected by this price increase. For this reason, $\frac{\partial \hat{p}_m}{\partial w_k^i}(w) = 0$ holds for any input price vector w and for any manufacturer m different to i and k.

An increase in input price w_k^i thus affects the demand for the output produced by manufacturer m only in two ways, by a change in output price p_k and by a change in output price p_i. The first transmission channel is henceforth called the direct price channel and the second one is

by w_{-k} and that of the downstream subsidiaries $i = 1, 2$ are unaffected by w^{-i}.

[12] Notice that a complete analysis of the pre-merger situation would require to derive these properties instead of simply assuming them. A full-fledged Bertrand competition model would be needed for such a derivation. However, we abstain here from this issue because such a game theoretical exercise is beyond the objective of this paper. We only note that our assumptions can be derived from a competition model in which (i) the manufacturers are faced with linear demand functions and (ii) the firms have static beliefs, i.e., they believe even at information sets off the equilibrium path that the competitors charge their equilibrium prices.

[13] We remark that this property might be violated in two-sided markets. In this case it could be profitable for firms due to the indirect network effects to subsidize one side of consumers. This finding is detailed in the analysis of Rochet and Tirole (2003). Upward pricing pressure indices for mergers in two-sided markets are derived in Affeldt et al. (2013). Cosnita-Langlais et al. (2018) amend these indices to incorporate feedback effects.

called the indirect price channel. In what follows, we take for granted that whenever the effect of the indirect price channel is counteracting the effect of the direct price channel, the latter outweigh the former. We back up this assertion by imposing further two assumptions. First, we suppose that the absolute size of the effect on the demand for product k through the direct transmission channel exceeds the size of the effect on the demand for product k through the indirect transmission channel, i.e.

$$\left|\frac{\partial D_k}{\partial p_k}(p)\frac{\partial \hat{p}_k}{\partial w_k^i}(w)\right| > \frac{\partial D_k}{\partial p_i}(p)\frac{\partial \hat{p}_i}{\partial w_k^i}(w)\,. \tag{3}$$

Second, we suppose that the size of the effect on the demand for product $m \neq k$ through the direct transmission channel exceeds the absolute size of the effect on the demand for product m through the indirect transmission, i.e.

$$\frac{\partial D_m}{\partial p_k}(p)\frac{\partial \hat{p}_k}{\partial w_k^i}(w) > \left|\frac{\partial D_m}{\partial p_i}(p)\frac{\partial \hat{p}_i}{\partial w_k^i}(w)\right|\,. \tag{4}$$

Summing up, our assumptions (2) to (4) ensure that, whenever the non-integrated manufacturer k employs the input offered by supplier i, an increase in the price of this input leads to an decrease in the demand for product k, but to an increase in the demand for any substitute $m \neq k$.

A perfect Bayesian equilibrium requires that the beliefs at the information sets crossing the equilibrium path be consistent with the factual price decisions. This postulate implies the following conjectures in our two-stage competition game. Each downstream division of a vertically integrated firm i believes at information set $\hat{w}^i$ that the upstream division of the other vertically integrated firm j charges its equilibrium input prices $\hat{w}^j$. Each non-integrated manufacturer k believes at information set $\hat{w}_k$ that its non-integrated competitors are charged the equilibrium input prices $\hat{w}_{-k}$. The other requirement imposed by the perfect Bayesian Nash equilibrium concept is that all players act sequentially rational at each of their information sets. This entails for our two-stage competition game that each firm maximizes its expected profits at each of its information sets. In what follows, we specify conditions on the equilibrium input and output prices resulting from sequential rationality and the above conjectures.

As a first step, we examine the price setting in the downstream market. We begin with considering the price strategy a vertically integrated firm i chooses in the downstream market. The profit of such a firm is given by

$$\pi_i(w,p) = (p_i - c_i)D_i(p) + \sum_{m=3}^{M}(w_m^i - c_m^i)S_m^i(w_m)D_m(p).$$

Obviously, firm i's profit depends on the output prices charged by all manufacturers as well as on the input prices charged by all suppliers. The first term on the right-hand side of the profit equation is the profit the vertically integrated firm i realizes in the downstream market while the second term denotes the profit it realizes by selling inputs to the non-integrated downstream competitors 3 to M.

As mentioned above, firm i believes at information set $\hat{w}^i$ that the other supplier j chooses the equilibrium input price vector $\hat{w}^j$. Such a conjecture implies that firm i expects at this information set that each competitor m in the downstream market chooses the equilibrium output price $\hat{p}_m = \hat{p}_m(\hat{w})$. Because firm i acts sequentially rational, the following first-order condition for a profit maximum with respect to output price p_i

$$\frac{\partial \pi_i}{\partial p_i}(\hat{w}, \hat{p}) = D_i(\hat{p}) + (\hat{p}_i - c_i)\frac{\partial D_i}{\partial p_i}(\hat{p}) + \sum_{m=3}^{M}(\hat{w}_m^i - c_m^i)S_m^i(\hat{w}_m)\frac{\partial D_m}{\partial p_i}(\hat{p}) = 0 \tag{5}$$

results at information set $\hat{w}^i$.

Next, we aim to specify the first-order conditions for the equilibrium prices set by the non-integrated manufacturers. The profit function of such a manufacturer k is given by

$$\pi_k(w, p) = \left(p_k - \sum_{i=1}^{2} w_k^i S_k^i(w_k)\right) D_k(p) \; .$$

Non-integrated manufacturers have only one source of revenue, the downstream market. According to our assumptions on the manufacturers' knowledge, these manufacturers observe at each of their information sets only the prices of their inputs, but not the input prices the suppliers arranged with the other downstream firms. As argued above, a non-integrated manufacturer k conjectures at its information set $\hat{w}^k$ that each non-integrated competitor m pays the equilibrium input prices $\hat{w}_m$. Consequently, manufacturer k expects at this information set that any of its competitors m sets the equilibrium output price $\hat{p}_m = \hat{p}_m(\hat{w})$. Sequential rationality at information set $\hat{w}_k$ implies that the equilibrium price $\hat{p}_k$ charged by the non-integrated manufacturer k satisfies the first-order condition

$$\frac{\partial \pi_k}{\partial p_k}(\hat{w}, \hat{p}) = \left(\hat{p}_k - \sum_{i=1}^{2} \hat{w}_k^i S_k^i(\hat{w}_k)\right) \frac{\partial D_k}{\partial p_k}(\hat{p}) + D_k(\hat{p}) = 0 \; . \tag{6}$$

As can be easily checked, condition (6) is equivalent to

$$\frac{\left(\hat{p}_k - \sum_{i=1}^{2} \hat{w}_k^i S_k^i(\hat{w}_k)\right)}{\hat{p}_k} = \frac{1}{\epsilon_k}, \tag{7}$$

where $\epsilon_k := -\frac{\partial D_k}{\partial p_k}(\hat{p})\frac{\hat{p}_k}{D_k(\hat{p})}$ denotes the (own) price elasticity of the demand for the output produced by non-integrated manufacturer k at the equilibrium output prices $\hat{p}$. Equation (7) is the well-known markup rule. It states that the profit margin of manufacturer k corresponds to the inverted value of the price elasticity of the demand for the output supplied by this manufacturer.

Having specified all first order conditions in the downstream market, we are able to solve the second step of our pre-merger equilibrium. For this purpose, consider a vertically integrated firm i which delivers inputs to the non-integrated manufacturer k, i.e. $S_k^i(\hat{w}) \neq 0$ holds.

Plugging the equilibrium price strategy profile $\hat{p}(\cdot)$ in the profit functions π_i of this vertically integrated firm, we obtain the indirect profit function $\hat{\pi}_i(w) := \pi_i(w, \hat{p}(w))$. The optimality conditions on the input prices charged by the vertically integrated firm i are derived from this function. Maximizing its indirect profit function implies that firm i takes into account the impact of its input prices on the output prices. The envelope theorem entails that the first-order condition with respect to the input prices w_k^i charged by the vertically integrated firm i to the non-integrated downstream firm k is given by

$$\begin{aligned}\frac{\partial \hat{\pi}_i}{\partial w_k^i}(\hat{w}) \;=\; & (\hat{p}_i - c_i)\frac{\partial D_i}{\partial p_k}(\hat{p})\frac{\partial \hat{p}_k}{\partial w_k^i}(\hat{w}) + S_k^i(\hat{w}_k)D_k(\hat{p}) + (\hat{w}_k^i - c_k^i)\frac{\partial S_k^i}{\partial w_k^i}(\hat{w}_k)D_k(\hat{p}) \\ & + \sum_{m=3}^{M}(\hat{w}_m^i - c_m^i)S_m^i(\hat{w}_m)\frac{\partial D_m}{\partial p_k}(\hat{p})\frac{\partial \hat{p}_k}{\partial w_k^i}(\hat{w}) = 0\,.\end{aligned} \tag{8}$$

Summing up, the input and output prices $(\hat{w}, \hat{p})$ realized in the perfect Bayesian equilibrium of our two-stage game have to satisfy the optimality conditions (5) to (8). These pre-merger equilibrium prices constitute the reference point of the merger analysis we conduct in the next section. To evaluate the anti-competitive effects of a merger between the two vertically integrated firms, the upward pricing pressure induced by the merger is measured from these prices.

4 The Situation Post-Merger

Suppose, the two vertically integrated firms merge into a new firm z. This firm comprises four divisions, two upstream divisions producing inputs 1 and 2 and two downstream divisions producing outputs 1 and 2. Whenever the merger does not induce cost synergies, the profit function of the new firm z is equal to

$$\begin{aligned}\pi_z^0(w,p) &:= \pi_1(w,p) + \pi_2(w,p) \\ &= (p_1 - c_1)D_1(p) + \sum_{m=3}^{M}(w_m^1 - c_m^1)S_m^1(w_m)D_m(p) \\ &\quad + (p_2 - c_2)D_2(p) + \sum_{m=3}^{M}(w_m^2 - c_m^2)S_m^2(w_m)D_m(p).\end{aligned}$$

Superscript 0 of the above profit function points to the assumption that this merger does not generate any efficiency gains in forms of cost reductions.

The current market environment which the merged firm is confronted with is the pre-merger equilibrium. As detailed in the previous section, this environment includes the following state of affairs. The current input and output prices are at the pre-merger equilibrium levels $\hat{w}$ and $\hat{p}$ satisfying the optimality conditions (5) to (8). Moreover, the information management of the merged firm has not yet been changed and corresponds to that before the merger. This

entails that the downstream division of a merging partner is still uninformed about the input prices set by the upstream division of the other merging partner.

Our objective is to provide meaningful indices measuring the intensity of the incentive the merged firm has to increase its input and output prices at the pre-merger equilibrium $(\hat{w}, \hat{p})$. The fundamental principle underlying such upward pricing pressure indices has been put forward by Werden (1996). His concept specifies the magnitude of the reduction in the marginal costs needed for offsetting the incentive of the merged firm to increase its prices. As suggested by Werden (1996), these hypothetical gains in cost efficiency should be taken as the measure for the intensity of this incentive. Upward pricing pressure indices thus display the size of the gains in cost efficiency required for the post-merger prices to remain at their pre-merger levels. The greater the value of the upward pricing pressure indices, the greater the reduction in marginal costs needed to keep the merged firm from increasing its prices and thus the more likely the merger turns out to be anti-competitive.

However, unlike the original construction approach of Werden (1996), our upward pricing pressure indices are derived from isolated price changes. This approach has been forcefully put forward by Farell/Shapiro (2010a). They suggest to evaluate the intensity of the incentive to increase the prices separately for each price set by the merged firm.[14] The intensity with which a division of the merged firm aims at increasing the price of its product is then measured by the efficiency gains of this division required to keep the product price unchanged after the merger. In doing so, the prices of any divisions and non-integrated firms which are not informed about a change in this price are held fixed. In particular, the prices of the divisions and non-integrated firms operating at the same or upper stage of the supply chain are kept at the pre-merger level. With this in mind, it becomes apparent that the calculations of the upward pricing pressure indices are not comparative statics exercises that contrast the equilibrium pre-merger with the one post-merger. Rather, starting from the pre-merger equilibrium, these indices evaluate the intensity with which the merged firm aims at increasing its prices by specifying the gains in cost efficiency needed for compensating such an incentive.

Obviously, this intensity depends on the extent to which such price increases affect the profit of the merged firm. The size of theses effects in turn depend on how the downstream divisions of the merged firm as well as its competitors react to the increase in price. If the merged firm increases one of its output prices, all other prices remain unchanged as this change is not observed by the other manufacturers. If the merged firm increases one of its input prices, all other prices remain unchanged except for two output prices. One of them is the price charged by the downstream division of the merging partner who increased the input price. The other price affected by this increase in the input price is the price charged by the non-integrated manufacturer who employs this input. Notice that the remaining manufacturers do not react

[14] A comprehensive and gentle introduction on the various construction approaches for upward pricing pressure indices is provided in Baltzopoulos et al. (2015). The authors particularly discuss the difference between the two-sided efficiency approach of Werden (1996) and the one-sided efficiency approach of Farell/Shapiro (2010a). As mentioned above, the construction of our upward pricing pressure indices follows the latter approach.

to the change in the input price as they do not observe this change in price and thus base their beliefs on the same information as in the situation pre-merger.

In the subsequent paragraphs we derive the upward pricing pressure indices for each of the prices set by the merged firm. In total, the merged firm might fix $2(M-1)$ prices, the $2(M-2)$ input prices set by its upstream divisions and the two output prices set by its downstream divisions. In line with the standard terminology, we term our indices the gross upward pricing pressure indices regarding a merger of two vertically integrated firms. We use henceforth the abbreviation $\texttt{iGUPPI}$ for these indices. Our analysis begins with the construction of the gross upward pricing pressure indices $\texttt{iGUPPI}_{\texttt{d}}$ for the two output prices. After that, we derive the gross upward pricing pressure indices $\texttt{iGUPPI}^{\texttt{u}}$ for the $2(M-2)$ input prices.

Following the methodology proposed by Farell/Shapiro (2010a) the upward pricing pressure index $\texttt{iGUPPI}^i_{\texttt{d}}$ gives the reduction in the marginal costs of the downstream division i needed to offset the incentive of this division to increase output price p_i. To derive this index, we thus assume that the merger of the two vertically integrated firms generates gains in cost efficiency for downstream division i in the amount of γ_i. In this case, the profit function of the merged firm takes the form

$$\begin{aligned}\pi^i_z(w,p) := \; & (p_i - c_i + \gamma_i)D_i(p) + \sum_{m=3}^{M}(w^i_m - c^i_m)S^i_m(w_m)D_m(p) \\ & + (p_j - c_j)D_j(p) + \sum_{m=3}^{M}(w^j_m - c^j_m)S^j_m(w_m)D_m(p).\end{aligned}$$

where j denotes the other merging partner. Superscript i of the above profit function relates to our assumption that the merger generates only gains in cost efficiency for the downstream division of merging partner i.

Taking into account the first-order condition (5), the change in the profit of the merged firm at the pre-merger equilibrium prices $(\hat{w},\hat{p})$ induced by an increase in its output price p_i corresponds to

$$\frac{\partial \pi^i_z}{\partial p_i}(\hat{w},\hat{p}) \; = \; \gamma_i \frac{\partial D_i}{\partial p_i}(\hat{p}) + (\hat{p}_j - c_j)\frac{\partial D_j}{\partial p_i}(\hat{p}) + \sum_{m=3}^{M}(\hat{w}^j_m - c^j_m)S^j_m(\hat{w})\frac{\partial D_m}{\partial p_i}(\hat{p}).$$

Analogous to Farell/Salop (2010a), we aim to figure out the magnitude of the reduction in the marginal costs of downstream division i preventing the merged firm from increasing output price p_i. Putting it differently, we have to specify the size of the cost efficiency parameter γ_i for which the above equation vanishes, i.e. $\frac{\partial \pi^i_z}{\partial p_i}(\hat{w},\hat{p}) = 0$ holds. We denote henceforth this critical value by $\hat{\gamma}_i$. Solving the last equation for $\hat{\gamma}_i$ and then dividing both sides by the pre-merger output price $\hat{p}_i$ we obtain

$$\frac{\hat{\gamma}_i}{\hat{p}_i} = \frac{(\hat{p}_j - c_j)\frac{\partial D_j}{\partial p_i}(\hat{p}) + \sum_{m=3}^{M}(\hat{w}^j_m - c^j_m)S^j_m(\hat{w})\frac{\partial D_m}{\partial p_i}(\hat{p})}{-\hat{p}_i \frac{\partial D_i}{\partial p_i}(\hat{p})}. \tag{9}$$

The expression on left-hand side of equation (9) states the required gains in cost efficiency for downstream division i in percentage of the pre-merger equilibrium price of i's product. The ratio on the right-hand side defines our gross upward pricing pressure index for output price p_i, shortly $\texttt{iGUPPI}^i_{\texttt{d}}$. It relates the additional profits accruing to merging partner j to the value of the lost sales of downstream division i due to an increase in price p_i.

We remark that the term of the numerator of our $\texttt{iGUPPI}^i_{\texttt{d}}$ decomposes the total effect of an increase in price p_i into two effects. The first summand of the numerator describes the effect on the demand for the product offered by merging partner j. Since the product of the downstream division j is a substitute to the product offered by downstream division i the demand for j's product increases as the price of i's product goes up. The second summand is the effect on the demand for the input offered by merging partner j. Due to the increase in the price of output i there is additional demand for the outputs of the non-integrated manufacturers. The increase in their production leads in turn to an increased demand for the inputs offered by the upstream division of the merging partner j.

Our assumptions on the demand functions and the no cross subsidization assumption (1) entail that the two effects described in the numerator of $\texttt{iGUPPI}^i_{\texttt{d}}$ are positive so that merging partner j unambiguously profits from the merger. Moreover, the denominator which measures the value of the lost sales of merging partner i is also positive. Consequently, our index $\texttt{iGUPPI}^i_{\texttt{d}}$ turns out to be positive, implying that any merger of vertical integrated firms induces an upward pressure on the prices set by their downstream divisions.[15]

Next, we aim at specifying the upward pricing pressure indices for the input prices charged by the upstream divisions of the merged firm. For this purpose, pick some supplier i which delivers inputs to some non-integrated manufacturer k. In mathematical terms, we suppose that $S^i_k(\hat{w}) > 0$ holds in the following derivation. As before, we proceed as suggested by Farell/Shapiro (2010a). We assume that the merger generates a reduction in the marginal costs of i's production for manufacturer k in the amount of γ^i_k. Given such gains in cost efficiency, the profit function of the merged firm takes the form

$$\begin{aligned}\pi^k_z(w,p) := \; & (p_i - c_i)D_i(p) + (w^i_k - c^i_k + \gamma^i_k)S^i_k(w_k)D_k(p) \\ & + \sum_{m=3, m\neq k}^{M} (w^i_m - c^i_m)S^i_m(w_m)D_m(p) \\ & + (p_j - c_j)D_j(p) + \sum_{m=3}^{M}(w^j_m - c^j_m)S^j_m(w_m)D_m(p)\end{aligned}$$

[15] One might substantiate this result by arguing that the merging firms are already vertically integrated and thus there is downward pricing pressure due to the avoidance of double marginalization. However, this argument holds only for the downstream divisions of the merged firm. Regarding the upstream divisions, such pricing pressure might occur. To see this, consider a downstream non-integrated manufacturer who utilizes the inputs of the two upstream divisions of the merged firm in a fixed ratio (i.e. in a complementary way). In such a case the merger might overcome the pre-merger problem of double marginalization with which the two competing suppliers and the non-integrated manufacturer are faced. We come back to this effect in Section 5 when we are applying our price indices to a merger example.

where j denotes the other merging partner. Superscript k of the above profit function points to our assumption that the merger brings about only efficiency gains regarding the production of supplier i for manufacturer k.

To capture the effect of an increase in input price w_k^i on the profit of the merged firm, we resort to the pre-merger equilibrium price strategies specified in the previous section. Plugging these price strategies into the profit function of the merged firm gives the indirect profit function

$$\hat{\pi}_z^k(w) := \pi_z^k(w, \hat{p}(w)) \; .$$

Partially differentiating this function with respect to input price w_k^i at the pre-merger equilibrium $(\hat{w}, \hat{p})$, we obtain the initial effect of an increase in input price w_k^i on the profit of the merged firm. Taking into account the first-order condition (8) and $\hat{p} = \hat{p}(\hat{w})$, the derivative is given by

$$\begin{aligned}
\frac{\partial \hat{\pi}_z^k}{\partial w_k^i}(\hat{w}) \;=\; & \gamma_k^i \frac{\partial S_k^i}{\partial w_k^i}(\hat{w}) D_k(\hat{p}) + \gamma_k^i S_k^i(\hat{w}) \left(\frac{\partial D_k}{\partial p_i}(\hat{p}) \frac{\partial \hat{p}_i}{\partial w_k^i}(\hat{w}) + \frac{\partial D_k}{\partial p_k}(\hat{p}) \frac{\partial \hat{p}_k}{\partial w_k^i}(\hat{w}) \right) \\
& + (p_j - c_j) \left(\frac{\partial D_j}{\partial p_i}(\hat{p}) \frac{\partial \hat{p}_i}{\partial w_k^i}(\hat{w}) + \frac{\partial D_j}{\partial p_k}(\hat{p}) \frac{\partial \hat{p}_k}{\partial w_k^i}(\hat{w}) \right) \\
& + (\hat{w}_k^j - c_k^j) \frac{\partial S_k^j}{\partial w_k^i}(\hat{w}_k) D_k(\hat{p}) \\
& + (\hat{w}_k^j - c_k^j) S_k^j(\hat{w}_k) \left(\frac{\partial D_k}{\partial p_i}(\hat{p}) \frac{\partial \hat{p}_i}{\partial w_k^i}(\hat{w}) + \frac{\partial D_k}{\partial p_k}(\hat{p}) \frac{\partial \hat{p}_k}{\partial w_k^i}(\hat{w}) \right) \\
& + \sum_{m=3, m \neq k}^{M} (\hat{w}_m^j - c_m^j) S_m^j(\hat{w}_m) \left(\frac{\partial D_m}{\partial p_i}(\hat{p}) \frac{\partial \hat{p}_i}{\partial w_k^i}(\hat{w}) + \frac{\partial D_m}{\partial p_k}(\hat{p}) \frac{\partial \hat{p}_k}{\partial w_k^i}(\hat{w}) \right) \; .
\end{aligned}$$

We aim to find out the magnitude of the efficiency gain γ_k^i needed for compensating the incentive of the upstream division i to increase its input price for manufacturer k. In mathematical terms, we have to specify the size of the efficiency gain γ_k^i implying $\frac{\partial \hat{\pi}_z^k}{\partial w_k^i}(\hat{w}) = 0$. The required efficiency gain is henceforth denoted by $\hat{\gamma}_k^i$. Solving the last equation for $\hat{\gamma}_k^i$ and then dividing both sides by the pre-merger input price $\hat{w}_k^i$ yields

$$\begin{aligned}
\frac{\hat{\gamma}_k^i}{\hat{w}_k^i} = \; & \Bigg[(\hat{p}_j - c_j) \left(\frac{\partial D_j}{\partial p_i}(\hat{p}) \frac{\partial \hat{p}_i}{\partial w_k^i}(\hat{w}) + \frac{\partial D_j}{\partial p_k}(\hat{p}) \frac{\partial \hat{p}_k}{\partial w_k^i}(\hat{w}) \right) \\
& + (\hat{w}_k^j - c_k^j) \frac{\partial S_k^j}{\partial w_k^i}(\hat{w}_k) D_k(\hat{p}) \\
& + (\hat{w}_k^j - c_k^j) S_k^j(\hat{w}_k) \left(\frac{\partial D_k}{\partial p_i}(\hat{p}) \frac{\partial \hat{p}_i}{\partial w_k^i}(\hat{w}) + \frac{\partial D_k}{\partial p_k}(\hat{p}) \frac{\partial \hat{p}_k}{\partial w_k^i}(\hat{w}) \right) \\
& + \sum_{m=3, m \neq k}^{M} (\hat{w}_m^j - c_m^j) S_m^j(\hat{w}_m) \left(\frac{\partial D_m}{\partial p_i}(\hat{p}) \frac{\partial \hat{p}_i}{\partial w_k^i}(\hat{w}) + \frac{\partial D_m}{\partial p_k}(\hat{p}) \frac{\partial \hat{p}_k}{\partial w_k^i}(\hat{w}) \right) \Bigg] \\
& \left[-\hat{w}_k^i \frac{\partial S_k^i}{\partial w_k^i}(\hat{w}_k) D_k(\hat{p}) - \hat{w}_k^i S_k^i(\hat{w}_k) \left(\frac{\partial D_k}{\partial p_i}(\hat{p}) \frac{\partial \hat{p}_i}{\partial w_k^i}(\hat{w}) + \frac{\partial D_k}{\partial p_k}(\hat{p}) \frac{\partial \hat{p}_k}{\partial w_k^i}(\hat{w}) \right) \right]^{-1} \; .
\end{aligned} \tag{10}$$

The expression on the left-hand side of Equation (10) states that the required gains in cost efficiency in percentage of the pre-merger equilibrium input price paid by manufacturer k to upstream division i. The term on the right-hand side defines our gross upward pricing pressure index for input price w_k^i, abbreviated henceforth with $\texttt{iGUPPI}_k^u$. This ratio relates the additional profits earned by merging partner j to the value of the lost sales of merging partner i due to an increase in price w_k^i.

The numerator of the term on the right-hand side of Equation (10) decomposes the total impact of the increase in input price w_k^i on the profit of the merging partner j into three effects:

(i) the effect on the profit earned by the downstream division of merging partner j,

(ii) the effect on the profit earned by the upstream division of merging partner j from the business relationship with the non-integrated manufacturer k,

(iii) the effect on the profit earned by the upstream division of merging partner j from the business relationship with the non-integrated manufacturers different to k.

Effect (i) is captured by the first summand of the numerator. As discussed above, an increase in input price w_k^i affects the prices of the products supplied by the downstream division of merging partner i and by the non-integrated manufacturer k. Since both products are imperfect substitutes to the product offered by the downstream division of merging partner j, the demand for this product might change. Indeed, our assumptions (2) and (4) imply that the increase in input price w_k^i induces an increase in the demand for product j. The latter influences positively the profit of the downstream division of merging partner j.

Effect (ii) is summarized by the second and third summand of the numerator. This effect can in turn be decomposed into two effects, an input substitution effect and an output substitution effect. The input substitution effect is described by the second summand. Notice that due to the increase in input price w_k^i the non-integrated manufacturer k is prompted to revise its production process. It might partly substitute inputs from other suppliers for the input offered by the upstream division of merging partner i. In particular, the non-integrated manufacturer k might partially replace this input with the input offered by the upstream division of the other merging partner j. Consequently, a positive effect on the profit of this division might result from this substitution of inputs.

The substitution effect in the downstream market unleashed by an increase in input price w_k^i is captured by the third summand of the numerator. It refers to the impact such a price increase has on the demand for the product offered by the non-integrated manufacturer k. As noted above, an increase in input price w_k^i affects the prices of the products supplied by the downstream division of merging partner i and by the non-integrated manufacturer k. The demand for manufacturer k's product is therefore subjected to both an own price effect and a cross price effect. Our assumptions (2) and (3) imply that the own price effect is stronger than the cross price effect so that the demand for manufacturer k's product falls. This, in turn,

causes a drop in the demand of manufacturer k for the input supplied by the upstream division of merging partner j. Hence, the substitution of outputs triggered by an increase in input price w_k^i might negatively affect the profit of this division. Summing up, the output substitution effect counteracts the input substitution effect we described in the previous paragraph. For this reason, the sign of effect (ii) is not determinable a priori.

Effect (iii) is captured by the fourth summand of the numerator. As we already know, an increase in input price w_k^i affects the prices of the products supplied by the downstream division of merging partner i and by the non-integrated manufacturer k. Theses products are assumed to be imperfect substitutes to the products offered by the non-integrated manufacturers $m \neq k$. Hence, the demand for the product of such a manufacturer is affected by an increase in input price w_k^i. More precisely, our premises (2) and (4) entail that this demand goes up due to an increase in input price w_k^i. This rise in the demand for manufacturer m's product, in turn, might trigger an increase in manufacturer m's demand for the input supplied by the upstream division of merging partner j. In consequence, the profit earned by this upstream division from its business relationship with the non-integrated manufacturers $m \neq k$ might be positively influenced by an increase in input price w_t^i.

The denominator of the term on the right-hand side of Equation (10) summarizes the total impact of the increase in price w_k^i on the sales of the upstream division of merging partner i to the non-integrated manufacturer k. As displayed by the two summands of the denominator, this impact can be decomposed into two effects, an input substitution effect and an output substitution effect. The first effect is captured by the first summand and operates in the following manner. The non-integrated manufacturer k might respond to an increase in input price w_k^i by adjusting its production process. In particular, it might partially substitute other inputs for the input offered by the upstream division of merging partner i. Such an input substitution entails that a lower quantity of inputs supplied by this upstream division is employed by manufacturer k per unit of output. As a consequence thereof, the substitution effect might reduce the sales of the upstream division of merging partner i to manufacturer k. The second effect on these sales is captured by the second summand. It describes the substitution effect on the output of manufacturer k due to the increase in input price w_k^i. Recall that an increase in input price w_k^i alters the prices of the products offered by the downstream division of merging partner i and the non-integrated manufacturer k. The demand for manufacturer k's product is thus affected by a change in its own price and a change in the price of one of its substitutes. Due our premises (2) and (3) the resulting change in the demand for manufacturer k's product is negative. This, in turn, affects negatively the demand of manufacturer k for the input supplied by the upstream division of merging partner i. Thus, the input substitution effect and the output substitution effect go into the same direction. For this reason, it is unambiguous that the sales of the upstream division of merging partner i to the non-integrated manufacturer k decreases due to an increase in input price w_k^i.

The sign of the pricing pressure indices $\texttt{iGUPPI}^{\texttt{u}}$ turns out to be indeterminate given the

assumptions we have imposed on our two-stage competition game, implying that it is not a priori established that the merged firm has an incentive to increase its input prices. This ambiguity results from the output substitution contained in effect (ii). Because an increase of input price w_k^i leads to an decrease in the demand for product k, the output substitution effect turns out to be negative whenever manufacturer k sources inputs from supplier j. The output substitution effect counteracts all other effects on the profit of merging partner j, i.e. the input substitution effect contained in effect (ii) and the two effects (i) and (iii). Interestingly, this ambiguity remains even if one additionally assumes that the impact of an increase in input price w_k^i on the output price p_i is negligible and the non-integrated manufacturer k operates with a fixed input ratio.[16] However, in the case that the upstream division of merging partner j delivers no inputs to manufacturer k, our pricing pressure indices $\texttt{iGUPPI}^{\texttt{u}}$ become definitely positive.

5 iGUPPIs for Input and Output Prices

Our upward pricing pressure indices we have derived in the previous section are aimed to score a merger between two vertically integrated firms. More precisely, they are designed to evaluate the incentives of such a merged firm to raise its prices. Our indices turn out to be in line with the evaluation principles outlined in the 2010 US Horizontal Merger Guidelines. We quote the explanation made on page 21 of this guideline.

> *Adverse unilateral price effects can arise when the merger gives the merged entity an incentive to raise the price of a product previously sold by one merging firm and thereby divert sales to products previously sold by the other merging firm, boosting the profits on the latter products. Taking as given other prices and product offerings, that boost to profits is equal to the value to the merged firm of the sales diverted to those products. [...]*

Moreover, the US Horizontal Merger Guidelines are very detailed on how the upward pricing pressure induced by a merger should be measured. They postulate in footnote 11:

> *For this purpose, the value of diverted sales is measured in proportion to the lost revenues attributable to the reduction in unit sales resulting from the price increase. Those lost revenues equal the reduction in the number of units sold of that product multiplied by that product's price.*

As required by this directive, each of our upward pricing pressure indices is like the standard `GUPPI` and `vGUPPI` concepts a ratio between two monetary amounts. Its numerator gives the additional profit a merging partner realizes if the other merging partner increases one of its prices. This additional profit which is known as the recapture of the merger is attributable

[16] We come back to this indeterminancy issue in the next section where we provide a numerical example for our price indices.

to the increase in sales of the merging partner's upstream and downstream division. The denominator of our indices captures the lost revenues of the merging partner who has increased one of its prices. This loss is attributable to the reduction of sales its downstream or upstream division undergo due to this price increase.

In what follows, we reformulate our upward pricing pressure indices in a way so that they can be calculated from observable market data. More precisely, by suitable transformations we trace back our indices to the following economic variables:

- diversion ratios DR_{km},
- profit margins M_k and M_k^i,
- cost-pass-through elasticities η_k^i,
- input coefficient elasticities σ_k^i,
- price transmission ratios δ_k^i.

These variables are detailed in the subsequent paragraphs.

Obviously, if manufacturer k increases the price of its product, some of its customers might switch to other products. In particular, some former customers of manufacturer k become customers of manufacturer $m \neq k$. The diversion ratio $DR_{km} := -\frac{\partial D_m}{\partial p_k}(\hat{p})/\frac{\partial D_k}{\partial p_k}(\hat{p})$ from manufacturer k to manufacturer m gives the share of k's lost sales which are captured by m due to an increase in the price of the product supplied by k. This ratio is calculated at the pre-merger equilibrium output prices $\hat{p}$. Obviously, the diversion ratio can be specified by $DR_{km} = \frac{\epsilon_{km}}{\epsilon_k}\frac{D_m(\hat{p})}{D_k(\hat{p})}$ where where $\epsilon_{km} := -\frac{\partial D_m}{\partial p_k}(\hat{p})\frac{p_k}{D_m(\hat{p})}$ is the cross price elasticity of demand for product m with respect to the price of product $k \neq m$ evaluated at the pre-merger equilibrium output prices $\hat{p}$. Diversion ratios have been introduced by Shapiro (1996) and Werden (1996) in merger analysis and have become one of the key concepts of the upward pricing pressure approach.

The profit margin M_k denotes the profit manufacturer k earns per sold unit in percentage of the pre-merger equilibrium price $\hat{p}_k$. Obviously, the profit margin of the downstream division of a vertically integrated firm i is given by $M_i := (\hat{p}_i - c_i)/\hat{p}_i$ while the one of a non-integrated manufacturer k is given by $M_k := (\hat{p}_k - \sum_{i=1}^{2} \hat{w}_k^i S_k^i(\hat{w}_k))/\hat{p}_k$. Recall that the markup rule (7) establishes the relationship $M_k = 1/\epsilon_k$ for any non-integrated manufacturer k. The profit margin $M_k^i := (\hat{w}_k^i - c_k^i)/\hat{w}_k^i$ denotes the profit the downstream division of the vertically integrated firm i earns per unit of input sold to manufacturer k in percentage of the pre-merger equilibrium input price $\hat{w}_k^i$.

An increase in the price w_k^i of the input sold to manufacturer k might be partially passed on to manufactures k's customers by means of a higher output price. The relative size of this effect is measured by $\eta_k^i := \frac{\partial \hat{p}_k}{\partial w_k^i}(\hat{w})\frac{\hat{w}_k^i}{\hat{p}_k}$, the cost-pass-through elasticity of the price of the product offered by manufacturer k with respect to the price of the input offered by supplier i

to manufacturer k. This elasticity is calculated at the pre-merger equilibrium input prices $\hat{w}$ and indicates approximately the percentage change in the price of manufacturer k's product due to an increase in input price $\hat{w}_k^i$ by one percent

A change in input price w_k^i might not only affect the output price of manufacturer k, but also its production process. Whenever the input offered by supplier i becomes more expensive, the manufacturer might modify its employed input combination, partially substituting other inputs for the input of supplier i. The relative change in the contribution of supplier j's input for manufacturer k's production is measured by the input coefficient elasticity $\sigma_k^{ij} := -\frac{\partial S_k^j}{\partial w_k^i}(\hat{w}_k)\frac{\hat{w}_k^i}{S_k^j(\hat{w}_k)}$, i.e., the elasticity of input j's coefficient of manufacturer k's production with respect to the price manufacturer k pays for input i. This elasticity is evaluated at the pre-merger equilibrium prices $\hat{w}$ and indicates approximately the percentage change in input j's coefficient of k's production due to an increase in input price $\hat{w}_k^i$ by one percent. To simplify our notation, we denote henceforth the own price input coefficient elasticity by σ_k^i instead of σ_k^{ii}.

As already discussed in Section 4, an increase in input price w_k^i influences the demand for the product offered by manufacturer m through two price transmission channels in our two-stage competition model. Recall that manufacturer k and the downstream division of merging partner i are the only firms who observe this price change. For this reason, only they can respond by adjusting their output prices. The price adjustment of manufacturer k has been referred to as the direct price channel and the price adjustment of the downstream division of merging partner i has been referred to as the indirect price channel. The relative significance of these price channels on the demand for manufacturer m's product is indicated by the ratio $\delta_{km}^i := \frac{\partial D_m}{\partial p_i}(\hat{p})\frac{\partial \hat{p}_i}{\partial w_k^i}(\hat{w}) / \frac{\partial D_m}{\partial p_k}(\hat{p})\frac{\partial p_k}{\partial w_k^i}(\hat{w})$. This ratio is henceforth termed the price transmission ratio of the demand for product m with respect to an increase in input price w_k^i at the pre-merger equilibrium price vector $(\hat{w}, \hat{p})$. Its numerator captures the change in the demand for product m caused through the indirect price channel, i.e., due to the change of output price p_i induced by an increase of input price w_k^i. Its denominator captures the change in the demand for product m caused through the direct price channel, i.e., due to the change of price p_k induced again by the increase of w_k^i. Our assumptions (2) to (4) guarantee that $\delta_{km}^i < -1$ is satisfied. By suitable transformation the price transmission ratio can be expressed as the product of a ratio of (cross) price elasticities and a ratio of (cross) cost pass-through elasticities. As can be easily checked, the relationship $\delta_{km}^i = \frac{\epsilon_{im}}{\epsilon_{km}}\frac{\eta_{ki}^i}{\eta_k^i}$ holds where $\eta_{km}^i := \frac{\partial \hat{p}_m}{\partial w_k^i}(\hat{w})\frac{w_k^i}{\hat{p}_m}$ is the cross cost-pass-through elasticity of the price of the product offered by the manufacturer m with respect to the price of the input offered by supplier i to manufacturer $k \neq m$ evaluated at the pre-merger equilibrium input prices $\hat{w}$. For the sake of simplification, we denote henceforth the price transmission ratio of the demand for product k with respect to input price w_k^i by δ_k^i instead of δ_{kk}^i.

In the following paragraphs, we reconsider our upward pricing pressure indices and transform them in a way so that they can be expressed by the economic variables described above.

Moreover, to illustrate the usefulness of this transformation we apply the derived formulas to a contrived merger example.

First, reconsider the upward pricing pressure indices $\texttt{iGUPPI}_\texttt{d}$ for the output prices charged by the merged firm. These indices have already been described by the term on the right-hand side of Equation (9). Dividing both the numerator and the denominator of this term by $-(\partial D_i/\partial p_i)(\hat{p})$, we obtain the formula

$$\texttt{iGUPPI}^i_\texttt{d} := \frac{DR_{ij}\hat{p}_j M_j + \sum_{m=3}^{M} DR_{im} S^j_m \hat{w}^j_m M^j_m}{\hat{p}_i} \tag{11}$$

where j denotes the merging partner of firm i and $S^j_m := S^j_m(\hat{w}_m)$ denotes the manufacturer m's production coefficient regarding the input offered by supplier j at the pre-merger equilibrium input prices $\hat{w}_m$.

Notice that due the above transformation the interpretation of our indices $\texttt{iGUPPI}_\texttt{d}$ turn out to be slightly different than that given in Section 4. Being more precise, the reference point of our interpretation is rescaled by this transformation. Recall that index $\texttt{iGUPPI}^i_\texttt{d}$ in the form of Equation (9) gives the additional profits and the value of the lost sales due to an increase of the output price p_i by one monetary unit. In contrast, the form presented in Definition (11) measures the additional profits and the value of the lost sales due to an increase of the output price p_i inducing a loss of sales for downstream division i by one physical unit.

Interestingly, our upward pricing pressure index for output price p_i proves to be the sum of two well-known upward pricing pressure indices. The ratio $(DR_{ij}\hat{p}_j M_j)/\hat{p}_i$ is nothing different than the gross upward pricing pressure index for horizontal mergers $\texttt{GUPPI}_i$ as derived by Salop/Moresi (2009). This ratio summarizes the upward pricing pressure resulting from the merger of the downstream divisions of 1 and 2. The ratio $(\sum_{m=3}^{M} DR_{im} S^j_m \hat{w}^j_m M^j_m)/\hat{p}_i$ is the gross upward pricing pressure index for vertical mergers $\texttt{vGUPPI}^i_\texttt{d}$ with respect to the output price p_i as suggested by Moresi/Salop (2013) in their Equation (A14).[17] It summarizes the upward pressure resulting from the merger between the downstream division of i and the upstream division of j on this price. We conclude from the composition of our $\texttt{iGUPPI}_\texttt{d}$ that if the GUPPI concept of Salop/Moresi (2009) or the $\texttt{vGUPPI}_\texttt{d}$ concept of Moresi/Salop (2013) is mistakenly applied to evaluating the merger between two vertically integrated firms then the upward pressure on the output prices is underestimated.

To demonstrate the usefulness of our upward pricing pressure indices they are applied to a contrived merger example. Consider a supply chain with two markets, an upstream market and a downstream market. For the sake of simplicity, we suppose that the production of one output unit requires exactly one unit of input. In the pre-merger situation, there are two independent vertically integrated firms 1 and 2 being active in both markets (i.e. no input foreclosure). Their upstream divisions $u1$ and $u2$ are the only suppliers of the input. Besides

[17] Indeed, this index has been termed vGUPPId1 by Moresi/Salop (2013). To be in line with our notation, we denote the index by $\texttt{vGUPPI}_\texttt{d}$.

their downstream divisions $d1$ and $d2$ there are three non-integrated manufacturers in the downstream market, 3, 4, and 5. Manufacturer 3 sources all inputs from supplier $u1$ whereas manufacturer 5 sources all inputs from supplier $u2$. Only manufacturer 4 employs inputs from both suppliers. Twenty percent of its inputs stem from upstream division $u1$ and the remaining eighty percent stem from upstream division $u2$. The supply relationships in the pre-merger market situation are depicted in the below figure.

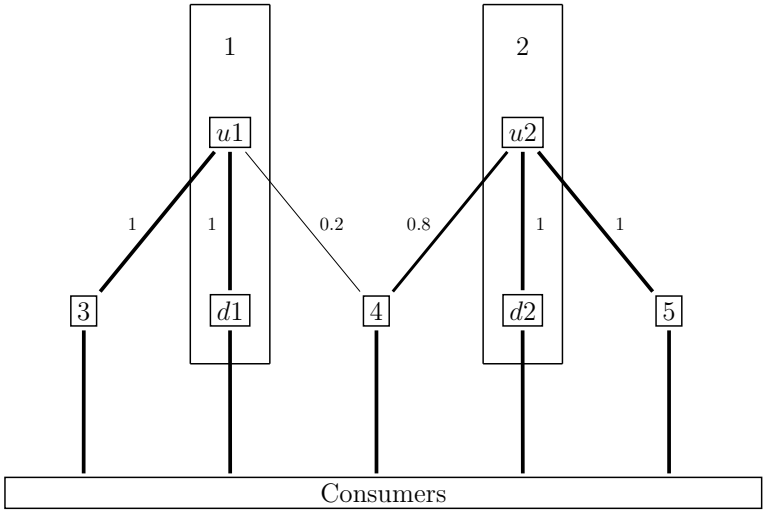

Figure 1: Situation pre-merger

According to the above assumptions on the supply relationships, the input coefficients of manufacturer 3 are equal to $S_3^1 := 1$ and $S_3^2 := 0$, that of manufacturer 4 are equal to $S_4^1 := 0.2$ and $S_4^2 := 0.8$, and that of manufacturer 5 are equal to $S_5^1 := 0$ and $S_5^2 := 1$. Moreover, we assume that the upstream division of each vertically integrated firm $i \in \{1, 2\}$ charges currently a price $\hat{w}_m^i := 0.5$ per unit of input to any non-integrated manufacturer $m \in \{3, 4, 5\}$. The downstream division of each vertically integrated firm $i \in \{1, 2\}$ charges a price $\hat{p}_i := 1$ per unit of output to its customers. The profit margins of the downstream divisions and upstream divisions amount to 50 percent, i.e., $M_i := 0.5$ and $M_m^i := 0.5$ hold for any vertically integrated firm $i \in \{1, 2\}$ and for any non-integrated manufacturer $m \in \{3, 4, 5\}$. We also assume that whenever one of the downstream divisions of the vertically integrated firms increases the price of its product, any other manufacturer captures 20 percent of the customers this division loses due to the price increase. Putting it differently, the diversion ratio between the product offered by downstream division i and the product offered by some manufacturer $m \in \{1, \ldots, 5\}$ where $m \neq i$ is assumed to be equal to $DR_{im} := 0.2$.

Now, suppose that the two vertically integrated firms intend to merge. By means of our upward pricing pressure indices $\texttt{iGUPPI}_\texttt{d}$ we are able to evaluate the intensity of the incentive such a merged firm has to increase the prices of its outputs. Before calculating this upward pricing pressure, we illustrate the effects summarized by these indices in Figure 2. This figure

highlights the forces behind the upward pressure on the product price p_1 charged by the downstream division of merging partner 1. An increase in this price leads to a decrease in the demand for the product of this division. However, as we already know, these losses are partially recaptured by the merging partner 2. The losses of the merging partner 1 and the gains of the merging partner 2 due to an increase in price p_1 are depicted by the grey lines in the below figure.

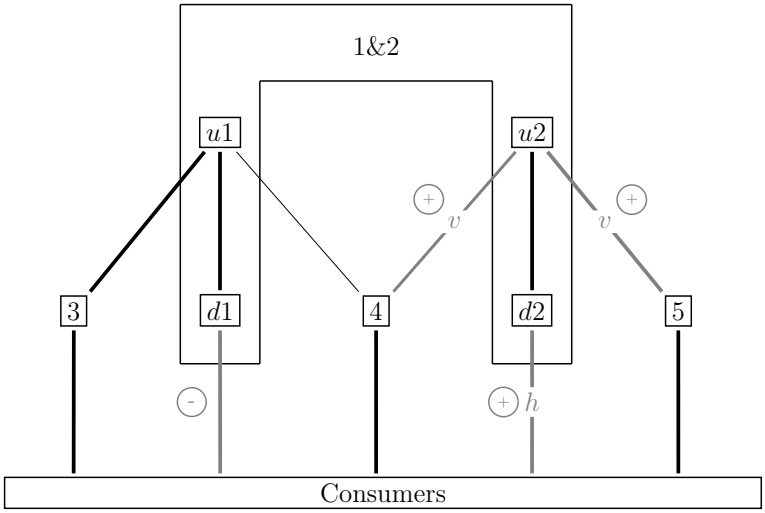

Figure 2: Sources of pressure on output price p_1 post-meger

As argued in Section 4, an increase in this price generates additional profits to merging partner 2 in two ways. The first one relates to the profit of its upstream division. Due to the increase in price p_1 the demand for the product offered by the upstream division of merging partner 2 goes up and thus additional profits are earned by this division. This effect is marked in the below figure by the lower-case letter h. It is the so-called horizontal upward pricing pressure of the merger. The second way relates to the profit of the downstream division of merging partner 2. Due to the increase in price p_1 the demand for the products offered by the non-integrated competitors also goes up. In consequence, these competitors sell more units of output and thus sources more inputs from their suppliers. In particular, some of these competitors might demand more inputs from the upstream division of merging partner 2. Hence, this upstream division earns a higher profit due to the increase in price p_1. This effect is marked by the lower-case letter v in Figure 2. It is the so-called vertical upward pricing pressure of the merger.

We apply our `iGUPPId` formula to quantify the upward pricing pressure on the prices of the outputs 1 and 2 due to a merger of the vertically integrated firms 1 and 2. Inserting the numerical values stipulated above in Definition (11), we obtain a gross upward pressure on the

price of output 1 in the amount of

$$\texttt{iGUPPI}_{\texttt{d}}^{1} = \frac{0.2 \times 1 \times 0.5 + 0.2 \times 0.8 \times 0.5 \times 0.5 + 0.2 \times 1 \times 0.5 \times 0.5}{1} = 0.19 \, .$$

This index number states that a unilateral increase in price for output 1 does not occur post-merger if the merger were to reduce the marginal cost of producing output 1 by 19 percentage of the pre-merger price for output 1. Because the price for this output has been set equal to 1 in our numerical example, this index reveals that the marginal cost of producing output 1 has to decrease by 0.19 monetary units in order to offset the incentive of the merged firm to increase the price of output 1. Notice that the assumed profit margin of downstream division $d1$ discloses that that pre-merger marginal cost of producing output 1 is equal to 0.5. Consequentially, only if the merger entails efficiency gains reducing at least this marginal cost by 38 percent, the merged firm abstains from increasing the price of output 1.

The gross upward price pressure on the price for output 2 is equal to

$$\texttt{iGUPPI}_{\texttt{d}}^{2} = \frac{0.2 \times 1 \times 0.5 + 0.2 \times 1 \times 0.5 \times 0.5 + 0.2 \times 0.2 \times 0.5 \times 0.5}{1} = 0.16 \, .$$

Obviously, the incentive of the merged firm to increase the price of output 2 is weaker than the one to increase the price of output 1. The reason for this is that the recapture of merging partner 1 due to an increase in output price p_2 is less than the recapture of merging partner 2 due to an increase in output price p_1. This difference can be finally traced back to the input combination employed by the non-integrated manufacturer 4. All other economic conditions are symmetric for the two merging partner. Whenever one of the output prices p_1 and p_2 increases, manufacturer 4 faces a greater demand for its product. However, because this manufacturer sources fewer inputs from upstream division $u1$ than from upstream division $u2$, the latter division profits more from this increase in demand.

Let us briefly come back to the fundamental issue on how to calculate the upward pricing pressure on an output price in case of a merger of two vertically integrated firms. Suppose merger analysts mistakenly take the standard `GUPPI` concept of Salop/Moresi (2009) or the `vGUPPI` concept of Moresi/Salop (2013) as the measure of the upward pricing pressure. In the first case, they would calculate an upward pricing pressure on output price p_1 in amount of $\texttt{GUPPI}_1 = 0.1$. In the second case, they come up with an upward pricing pressure for this price of $\texttt{vGUPPI}_{\texttt{d}}^{1} = 0.09$. Both values underestimate the true incentive of the merged firm by about 50 percent. We infer from this simple numerical example that applying the appropriate index formula is crucial for evaluating correctly the upward pricing pressure induced by a merger.

Our next task is to reformulate also the upward pricing pressure indices $\texttt{iGUPPI}^{u}$ for the input prices charged by the merged firm so that they are expressed by the economic variables presented at the beginning of this section. These indices have already been specified on the right-hand side of Equation (10). Dividing both the numerator and the denominator by $-\frac{\partial D_k}{\partial p_k}(\hat{p})\frac{\partial p_k}{\partial w_k^i}(\hat{w})$ and applying the mark-up rule (7), our gross upward price pressure index

$\texttt{iGUPPI}^{\texttt{u}}_{i,k}$ with respect to input price w^i_k takes the form of

$$\texttt{iGUPPI}^{\texttt{u}}_{i,k} := \frac{(1+\delta^i_{kj})DR_{kj}\hat{p}_j M_j - \left(1+\delta^i_k+\frac{M_k\sigma^{ij}_k}{\eta^i_k}\right)S^j_k\hat{w}^j_k M^j_k + \sum_{\substack{m=3\\m\neq k}}^{M}(1+\delta^i_{km})DR_{km}S^j_m\hat{w}^j_m M^j_m}{\left(1+\delta^i_k+\frac{M_k\sigma^i_k}{\eta^i_k}\right)S^i_k\hat{w}^i_k}. \tag{12}$$

where j denotes the merging partner of i and $S^i_m := S^m := S^i_m(\hat{w}_m)$ denotes the manufacturer m's production coefficient with respect to the input offered by supplier i at the pre-merger equilibrium input prices $\hat{w}_m$.

We note that by the above transformation the interpretation of the numerator and the denominator of $\texttt{iGUPPI}^u_{i,k}$ is modified. Recall that in the form of Definition (10) the numerator gives the additional profits of merging partner j and the denominator gives the value of the lost sales of merging partner i due to an increase in input price w^i_k by one monetary unit. The above transformation rescales the reference point of this interpretation. More precisely, in Definition (12) the numerator captures the additional profits of merging partner j and the denominator captures the value of the lost sales due to an increase in input price w^i_k so that the direct price channel induces a decrease of the demand for product k by one physical unit.

Apart from the different reference points, the effects summarized in the numerator and denominator of the term in Definition 12) are the same as described in Section 4. The first summand of the numerator is effect (i) and captures the effect of the input price increase on the profit earned by the downstream division of merging partner j. The second summand corresponds to effect (ii) and captures the effect on the profit earned by the upstream division of merging partner j from its business relationship with non-integrated manufacturer k. As noted in Section 4, this effect can further be decomposed into two effects. The factor $(1+\delta^i_k)$ relates to the so-called output substitution effect. It results from the lower output of manufacturer k because of its higher production costs. The factor $(M_k\sigma^{ij}_k)/\eta^i_k$ relates to the so-called input substitution effect. It results from the substitution of input j for input i since the latter input has become more expensive. The rightmost summand of the numerator describes effect (iii) and captures the effect on the profit earned by the upstream division of merging partner j from its business relationship with the non-integrated manufacturers different to k. The above index formula is quite complex. In the following we impose additional assumption regarding the price reactions of the manufacturers and the substitutability of the inputs so that this formula can interpreted more easily.

If we assume that the downstream division of merging partner i does not react to the price change induced by its upstream division (i.e. $\frac{\partial\hat{p}_i}{\partial w^i_k}(\hat{w}) = 0$ and thus $\delta^i_{k,m} = 0$ for any independent manufacturer m), then our index $\texttt{iGUPPI}^{\texttt{u}}_{i,k}$ for input price w^i_k reduces to

$$\texttt{iGUPPI1}^{\texttt{u}}_{i,k} := \frac{DR_{kj}\hat{p}_j M_j - \left(1+\frac{M_k\sigma^{ij}_k}{\eta^i_k}\right)S^j_k\hat{w}^j_k M^j_k + \sum_{m=3,m\neq k}^{M}DR_{km}S^j_m\hat{w}^j_m M^j_m}{\left(1+\frac{M_k\sigma^i_k}{\eta^i_k}\right)S^i_k\hat{w}^i_k}. \tag{13}$$

By the latter assumption, the demand for the product offered by manufacturer k is affected only by the direct channel. Hence, we consider an increase in input price w_k^i generating a decrease in the demand for product k by one physical unit in our interpretation of Definition (13).

Moreover, the first summand of the above formula corresponds exactly to the $\texttt{vGUPPI}^{\texttt{u}}_{i,k}$ formula derived by Moresi/Salop (2013) in their Equation (5) for the case of input substitution.[18]. This term captures the upward pressure resulting from the merger of the upstream division of firm i and the downstream division of firm j on the input price w_k^i. It is the vertical pressure induced by a merger of two vertically integrated firms on this price. The sum of the second and third summand turns out to be the GUPPI formula for the merger of two upstream multi-product firms.[19] This sum captures the upward pressure resulting from the merger between the upstream divisions of firm i and firm j on input price w_k^i. It is called the horizontal pressure generated by a merger of two vertically integrated firms on this price.

If we additionally assume that there is no input substitution, i.e. $\sigma_k^{ij} = 0$ holds for any suppliers i, j and any manufacturer k, our index $\texttt{iGUPPI}^{\texttt{u}}_{i,k}$ is further simplified to

$$\texttt{iGUPPI2}^{\texttt{u}}_{i,k} := \frac{DR_{kj}\hat{p}_j M_j - S_k^j \hat{w}_k^j M_k^j + \sum_{\substack{m=3,\\ m\neq k}}^{M} DR_{km} S_m^j \hat{w}_m^j M_m^j}{S_k^i \hat{w}_k^i} \,. \tag{14}$$

Unlike the more general index $\texttt{iGUPPI1}^{\texttt{u}}_{i,k}$, the sign of the second summand in the numerator of $\texttt{iGUPPI2}^{\texttt{u}}_{i,k}$ turns out to be unambiguously negative. This sign indicates that the profit of the upstream division of merging partner j earned with the business relationship with manufacturer k drops whenever the upstream division of merging partner i charges a higher price for the inputs employed by manufacturer k.

In the following, we aim to calculate the upward pressure on the input prices for the merger example we described above. For this purpose, we assume that the assumptions underlying our indices $\texttt{iGUPPI2}^{\texttt{u}}$ apply to our example. The upstream divisions of the integrated firms thus do not react to changes in the input prices charged by their downstream divisions and all manufacturers produce with fixed input coefficients, i.e., the manufactures cannot replace inputs from one supplier with inputs from the other suppliers. Before specifying quantitatively the upward pricing pressure induced by a merger between the two vertically integrated firms 1 and 2, we illustrate the different forces behind this pressure in Figure 3.

This figure shows the forces behind the upward pricing pressure on the input price w_4^1 charged by upstream division $u1$ to manufacturer 4. The lost revenues of upstream division $u1$ and the changes in the profit of merging partner 2 due to an increase in input price w_4^1 are depicted by the grey lines. As argued in Section 4, we can identify three effects on the profit of merging

[18] Indeed, Moresi/Salop (2013) denote these indices by $\texttt{vGUPPIu}$.

[19] The derivation of this variant of the GUPPI follows the standard approach. The only difference between this derivation and our derivation in Section 4 is that we have to take into account in the former derivation that the two merging firms do not operate in the downstream market. Indeed, the profit function of such an upstream firm i would be given by $\pi_i(w,p) = \sum_{m=3}^{M}(w_m^i - c_m^i)S_m^i(w_m)D_m(p)$.

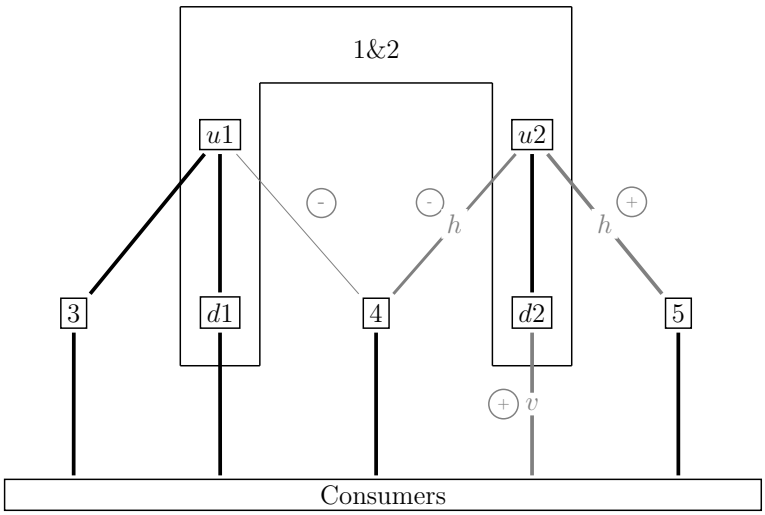

Figure 3: Sources of pressure on input price w_4^1 post-merger

partner 2 resulting from such a price increase. The first one is the effect on the profit of its upstream division. Owing to the increase in input price w_4^1 the marginal cost of manufacturer 4 rises. Manufacturer 4 partly pass on the increase of its marginal costs to its customers through a higher product price. In consequence, some of its customers are prompted to switch to other manufacturers, e.g. to the downstream division of merging partner 2. This recapture of downstream division $d2$ constitutes the so-called vertical upward pressure on input price w_4^1. It is marked by the lower-case letter v in Figure 3 and is definitely positive.

In addition to this effect, an increase in input price w_4^1 impacts the profit of the upstream division of merging partner 2. This happens in two ways. First, because one of its inputs becomes more expensive manufacturer 4's competitiveness is reduced. Manufacturer 4 sells fewer products. Moreover, since it operates with a fixed input ratio the increase in input price w_4^1 leads to no substitution of input 2 for input 1. As a consequence, manufacturer 4 demands fewer inputs from both upstream divisions. In particular, the profit of the upstream division $u2$ diminishes. The other effect relates to the input demand of manufacturer 5. The deteriorating competitiveness of manufacturer 4 induces a boost in the demand for the product offered by manufacturer 5. Such a boost entails that manufacturer 5 demands more inputs from upstream division $u2$. This increase in demand in turn raises the profit of upstream division $u2$. The two effects just described on the profit of upstream division $u2$ constitute the horizontal pressure on the input price w_4^1. It is marked by the lower-case letter h in Figure 3. Notice that the two effects are counteracting forces so that the sign of the horizontal pricing pressure is a priori undetermined.

To quantify the upward pressure on the input prices for our merger example we apply the above `iGUPPI2`$^{\mathtt{u}}$ formulas. Notice first that the pricing pressure indices cannot be calculated for the input price w_5^1 and w_3^2 because there is no pre-merger business relationship between

supplier 1 and manufacturer 5 as well as between supplier 2 and manufacturer 3. Regarding input price w_3^1, we obtain a gross upward pricing pressure in the amount of

$$\texttt{iGUPPI2}^{\texttt{u}}_{1,3} = \frac{0.2 \times 1 \times 0.5 + 0.2 \times 0.8 \times 0.5 \times 0.5 + 0.2 \times 1 \times 0.5 \times 0.5}{0.5} = 0.38 \, .$$

This index number reveals that an unilateral increase in input price w_3^1 would not occur post-merger if the merger were to reduce the marginal cost of the upstream division $u1$ in producing inputs for manufacturer 3 by 38 percentage of the pre-merger price of this input. Because the latter price has been assumed to be equal to 0.5, a reduction in the marginal cost of 0.19 monetary units is thus needed to offset the upward pricing pressure induced by the recapture of merging partner 2. Recall that the profit margin of the upstream division $u1$ regarding its supply relationship with manufacturer 3 has been set equal to 0.5. We infer from this margin that $u1$'s pre-merger marginal cost of producing inputs for manufacturer 3 amounts to 0.25. Therefore, only in the case that the merger generates a reduction of this marginal cost by 76 percent, the merged firm keeps the input price w_3^1 at its pre-merger level.

The gross upward pressure on input price w_4^1 is equal to

$$\texttt{iGUPPI2}^{\texttt{u}}_{1,4} = \frac{0.2 \times 1 \times 0.5 - 0.8 \times 0.5 \times 0.5 + 0.2 \times 1 \times 0.5 \times 0.5}{0.2 \times 0.5} = -0.5 \, .$$

The negative number of this index states that even if the merger does not entail cost efficiency gains in the manner that the upstream division $u1$ can produce inputs for manufacturer 4 with lower costs, the merged firm would nevertheless decrease the price of the input for manufacturer 4. Prima facie, this result might seem strange. If we look more closely at the situations pre- and post-merger, however, it becomes clear why this occurs. The reason is that the problem of double marginalization prevailing pre-merger is resolved by the merger. To see this, recall our above finding that if one of the inputs becomes more costly for manufacturer 4, this manufacturer demands fewer inputs from both suppliers. In the situation pre-merger, each upstream division disregards the losses accruing to the other upstream division if it raises the price of the input offered to manufacturer 4. A consequence of this ignorance is that the two divisions might charge overly high prices being unfavorable for both of them. However, the negative externality just described is taken into account by the two divisions post-merger so that they have an incentive to cut the prices of these inputs. Indeed, for the upstream division $u1$, this downward pricing pressure dominates the opposite pricing pressures.

The gross upward pressure on the input price w_4^2 is given by

$$\texttt{iGUPPI2}^{\texttt{u}}_{2,4} = \frac{0.2 \times 1 \times 0.5 - 0.2 \times 0.5 \times 0.5 + 0.2 \times 1 \times 0.5 \times 0.5}{0.8 \times 0.5} = 0.25 \, .$$

Unlike upstream division $u1$, upstream division $u2$ is prompted to increase the price of the input offered to manufacturer 4 after the merger. The divergence results from the fact that manufacturer 4's fixed coefficients with respect to the inputs offered by the two upstream divisions differ. Recall that its coefficient with respect to the input offered by $u1$ is 0.2 while its coefficient with respect to the input offered by $u2$ is 0.8. This difference entails that if

upstream division $u2$ raises the price of the input offered to manufacturer 4, the losses of upstream division $u1$ are lower than the other way around. Since upstream division $u2$ hurts the other upstream division to a relatively small extent by increasing this price, the resulting downward pricing pressure is relatively weak and is finally outweighed by the opposite pricing pressures.

Regarding input price w_5^2, we obtain an upward pricing pressure in the amount of

$$\texttt{iGUPPI2}^{\texttt{u}}_{2,5} = \frac{0.2 \times 1 \times 0.5 + 0.2 \times 1 \times 0.5 \times 0.5 + 0.2 \times 0.2 \times 0.5 \times 0.5}{0.5} = 0.32 \; .$$

This value falls short of $\texttt{iGUPPI2}^{u}_{1,3}$, which we calculated above. The divergence relies also on the fact that the manufacturer 4's fixed coefficients with respect to its two inputs are different. Because of this difference the recapture of upstream division $u1$ due to an increase in input price w_5^2 is less than the recapture of upstream division $u2$ due to an increase in input price w_3^1. Hence, the incentive of upstream division $u2$ to increase input price w_5^2 is less pronounced than that of upstream division $u1$ to increase input price w_3^1.

Summing up, the above iGUPPI2 values indicate how strong the incentive of the vertically integrated firms of our example is to increase their prices post-merger. If the merger does not generate sizable cost efficiencies in the production of their outputs, their downstream divisions have a strong incentive to increase their product prices. This would entail that the final consumers become worse off after the merger. Moreover, the competitiveness of manufacturer 3 and 5 might be considerably deteriorating post-merger. Indeed, as displayed by the above $\texttt{iGUPPI2}^{\texttt{u}}$ values, the highest upward pressure is on the input prices charged by the merged firm to these manufacturers. It turns out that the marginal costs of producing the inputs for manufacturer 3 and for manufacturer 5 has to decrease by 76 percent and 74 percent, respectively, in order to prevent an increase in these prices. Interestingly, the impacts of the merger on manufacturer 4 are ambiguous. Even if there are no cost efficiency gains in the production of the inputs for manufacturer 4, the upstream division of merging partner 1 has a strong incentive to decrease the price of the input offered to this manufacturer. The reason behind this downward pricing pressure is that the problem of double marginalization with which the suppliers are faced pre-merger is eliminated by the merger. However, we also have to keep in mind that the downward pricing pressure originating from the avoidance of this problem is relatively weak for the upstream division of merging partner 2. Indeed, this division might increase the price of the input offered to manufacturer 4 whenever it undergoes no substantial cost efficiency gains in the production of this input after the merger.

6 Conclusions

This paper has extended the analysis of pricing pressure indices to the case of a merger between two vertically integrated firms. Such mergers have been recently observed especially in the telecommunication sector, e.g. the Telefónica Deutschland/E-Plus merger in 2014. To the

author's best knowledge this paper is the first one which derives gross upward pricing pressure indices for this important type of merger.

Our derivation is based on the model proposed by Moresi/Salop (2013). We consider a two-stage differentiated Bertrand competition model with imperfect information. In this model, there is supply chain with two value creation stages, the upstream stage and the downstream stage. The upstream firms (i.e. the suppliers) set the prices of the intermediate goods used by the downstream firms (i.e. the manufacturers) before the latter ones set the prices of the final goods. While any non-integrated manufacturer is only informed about the prices of the inputs it employs, the manufacturer of any vertically integrated firm knows all input prices charged by the supplier of this firm. The pre-merger situation is assumed to be a perfect Bayesian equilibrium of this two-stage competition game.

Upward pricing pressure indices are aimed for quantifying the intensity of the incentive a merged firm has to increase the prices of its products. The `iGUPPI` derived in this paper measures this intensity for the case of a merger between two vertically integrated firms. For such mergers, we identify two forces behind the upward pricing pressure, a horizontal pricing pressure and a vertical pricing pressure. If a division of a merging partner increases the price of its product, then the losses induced by this price increase are partly recaptured by the divisions of the other merging partner. The horizontal pricing pressure results from the recapture of the other merging partner's corresponding division. The vertical pricing pressure results from the recapture of the other merging partner's lower-level or upper-level division.

Interestingly, our upwarding pricing pressure indices $\texttt{iGUPPI}_\texttt{d}$ for the output prices prove to be the sum of the `GUPPI` of Salop/Moresi (2009) and the $\texttt{vGUPPI}_\texttt{d}$ of Moresi/Salop (2013). The first one describes the horizontal upward pressure and the second one the vertical upward pressure on the output prices set by the two vertically integrated merging partners. An important conclusion of this decomposition is that whenever such a merger is mistakenly scrutinized by either the `GUPPI` concept or the $\texttt{vGUPPI}_\texttt{d}$ concept, the upward pressure on the output prices might be underestimated.

Unlike $\texttt{iGUPPI}_\texttt{d}$, our upward pricing pressure indices $\texttt{iGUPPI}^\texttt{u}$ for the input prices is not decomposable in such a simple way a priori. In this case, it is justifiable to say that the whole is greater than the sum of its parts. The reason is that an increase in an input price brings about two price reactions in the downstream market, a price reaction of the non-integrated manufacturer whose input has become more costly and a price reaction of the downstream division of the merging partner whose upstream division has increased the input price. The latter price reaction is incorporated neither in the `GUPPI` concept of Salop/Moresi (2009) nor in the $\texttt{vGUPPI}_\texttt{u}$ concept of Moresi/Salop (2013). However, if the price reaction of the downstream division is viewed as negligible, then our index $\texttt{iGUPPI}^\texttt{u}$ proves to be the sum of a multi-product upstream market version of `GUPPI` and $\texttt{vGUPPI}^\texttt{u}$.

The sign of our indices $\texttt{iGUPPI}_\texttt{d}$ for the output prices are definitely positive owing to our

assumption that the manufacturers produce imperfect substitutes. However, the sign of our indices $\texttt{iGUPPI}^{\texttt{u}}$ for the input prices are ambiguous. The reason is that some manufactures might employ their inputs in a complementary way. In the situation pre-merger, such production processes give rise to the problem of double marginalization. The competing upstream divisions of the vertically integrated firms are prompted to charge overly high input prices being unfavorable for both of them. A merger eliminates this problem, unleashing a downward pressure on the input prices. In some instances, this downward pricing pressure might outweigh the opposite pricing pressures induced by the merger.

An interesting question we leave for future research is to find out how robust our upward pricing pressure indices are with respect to the premises we have imposed on our competition model. For example, one might examine how changes in the information structure or the timing of the price-setting alter our index formulas. In this context, one could also abandon our assumption that the downstream division of a vertically integrated firm sources all inputs from its upstream division. Another issue future research might tackle is how our indices are related to the prices prevailing post-merger. Shapiro (1996) has already addressed this issue for the case of horizontal mergers. It turns out that the merged firm increases each of its prices by $\frac{1}{2(1-D)}\texttt{GUPPI}$ percent whenever the merging partners i and j are confronted with the same market conditions, i.e with the same constant marginal costs and with linear demand functions so that the diversion ratios $D := DR_{ij} = DR_{ji}$ between them are equal.[20] It might be interesting to find out whether there exists an analogous relationship between the values of our iGUPPI and the size of the price changes induced by a merger of vertically integrated firms. As noted in the Introduction, Bergh et al. (2017) analyze the price effects of such a merger in a specific market environment. It is an open question how their predicted price effects are related to our iGUPPI.

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