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Intimidating Competitors—Endogenous Vertical Integration and Downstream Investment in Successive Oligopoly

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We examine the interplay of endogenous vertical integration and cost-reducing downstream investment in successive oligopoly. We start from a linear Cournot model to motivate our more general reduced-form framework. For this general framework, we establish the following main results: First, vertical integration increases own investment and decreases competitor investment (intimidation effect). Second, asymmetric equilibria typically involve integrated firms that invest more into efficiency than their separated counterparts. Our findings suggest that asymmetric vertical integration is a potential explanation for the initial difference between leader and laggard in investment games.

Keywords: vertically related oligopolies, investment, vertical integration, cost reduction

JEL: L13, L20, L22

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1 Introduction

There is an extensive theoretical literature on endogenous vertical integration in successive oligopoly. This literature has addressed two key issues: (i) What will the industry's vertical structure look like in equilibrium? Specifically, in a setting where upstream and downstream firms are symmetric initially, can we expect an asymmetric vertical structure with integrated and separating firms coexisting? (ii) What are the relations among industry structure and performance? Particularly, should antitrust authorities be wary of asymmetric market structure?

As yet, no consensus seems to have emerged. While game-theoretic work has demonstrated that asymmetric vertical market structure may arise endogenously (see, e.g., Ordover et al. 1990, Elberfeld 2002, Jansen 2003, and Dufeu 2004), there is considerable debate about the robustness of this result. This is reflected in a recent paper by Buehler and Schmutzler (2005), who argue that there are good reasons why vertical integration decisions tend to be strategic substitutes, but also emphasize potential countereffects.

Interestingly, this literature has paid little attention to the interplay of vertical integration and investment in R&D. At the same time, the voluminous R&D literature has rarely focused on the links between investment in R&D and vertical market structure. In fact, we are aware of only two recent contributions focusing on the interplay of vertical market structure and investment decisions in successive oligopoly. Comparing given vertical structures, Banerjee and Lin (2003) show that downstream oligopolists may invest more in cost-reducing R&D than a downstream monopolist. Intuitively, the result follows from the output-enhancing effect of R&D, which allows the upstream monopoly to raise the input price, raising rivals' costs. Allowing for endogenous vertical integration, Brocas (2003) highlights that, in the case of upstream-innovation, endogenous vertical integration modifies the incentives to invest in R&D.

In the present paper, we extend previous research along three dimensions. First, we show that endogenous vertical integration modifies the incentives for cost-reducing investment in the downstream market. More specifically, we demonstrate that a firm's vertical integration increases its own incentive to invest into improving its efficiency but decreases the competitor's incentive to do so. The latter effect on the competitor—the *intimidation effect* of vertical integration—implies that there is a strategic incentive to integrate vertically. Put differently, vertical integration may serve as a top dog strategy (Fudenberg and Tirole 1984) geared towards tapering the competitor's cost-reducing investments.

Second, we show that the strategic integration incentive is likely to be larger for a firm facing a separated competitor than for a firm facing an integrated competitor due to demand/mark-up complementarities in the product market. As a result, asymmetric equilibria typically involve integrated firms that invest more into efficiency than their separated counterparts. Put differently, our analysis suggests that, in asymmetric equilibria, we are likely to observe large integrated and small separated firms. This finding is in line with the market structure of a number of vertically-related industries documented in the literature.[1]

Third, our analysis sheds new light on the discussion of endogenous market dominance. A large literature uses dynamic investment models suggesting how such dominance may emerge in a setting where there are initially small differences between a leader and a laggard.[2] Specific emphasis is placed on the idea that leaders with low costs (and thus high demand) often have stronger incentives to reduce their costs even further because this is more worthwhile, given their high demand. Even though the present paper treats only one period of the investment game explicitly, it suggests a mechanism by which integration can create the asymmetry between a leader and a laggard: Without vertical integration, our firms would always choose identical investment levels and thus remain symmetric. The binary nature of the integration decision changes this, as it makes asymmetric industry structures possible, which are then reinforced by the cost-reducing investment decisions.

[1] These include the oil industry (Bindemann 1999), the beer industry in the UK (Slade 1998a), the gasoline retail market in Vancouver (Slade 1998b), the US cable television industry (Waterman and Weiss 1996, Chipty 2001), the Mexican footwear industry (Woodruff 2002) and the UK package holiday industry (European Commission 1999).

[2] This has been discussed for incremental investment games (Flaherty 1980), learning-by-doing models (Cabral and Riordan 1994) or switching cost models (Beggs and Klemperer 1992); Athey and Schmutzler (2001) provide an integrated approach.

We establish our results in a framework where two downstream firms face at least two upstream suppliers. To produce one unit of the final product, downstream firms require one unit of an intermediate good produced by upstream firms. Downstream marginal costs consist of the costs of obtaining the intermediate good plus the costs of transforming the intermediate good into the final product. Initially, all firms are vertically separated. In stage 1, downstream firms decide whether to integrate backwards by acquiring a supplier, thereby getting access to the intermediate good at marginal costs. In stage 2, downstream firms can invest into reducing the costs of transforming the intermediate good into the final product, thereby increasing their transformation efficiency. In stage 3, the wholesale price is determined at which separated downstream firms are supplied. In stage 4, product market competition takes place.

We treat stages 3 and 4 in reduced form, working with a set of assumptions that serve to illustrate the idea that integration decisions and investment decisions interact. Specifically, we assume that a firm's integration decreases own costs and increases rivals' costs. Intuitively, this assumption on the effects of integration reflects the presence of *efficiency effects* and *foreclosure effects*. As we shall argue in Section 3.2, these effects have been identified in the literature as plausible consequences of vertical integration, even though they must not necessarily arise either in the real world or in theoretical models.[3] In any case, the presence of efficiency and foreclosure effects is sufficient, but not necessary as a justification of our assumption. If, contrary to our assumptions vertical integration were to *increase* own costs and to *decrease* rivals costs (or leave them unaffected), the opposite mechanisms would arise: There would be a strategic reason to refrain from integration.

The remainder of the paper is organized as follows. In section 2, we discuss a special Cournot example to set the stage. In section 3, we present the main results for our more general reduced-form model. Section 4 concludes.

[3] For instance, vertical integration will often reduce both demand and supply on the upstream market, with ambiguous effect on the upstream price. As a result, foreclosure effects will not necessarily occur in successive oligopoly models.

2 An Introductory Cournot Example

To motivate our reduced-form analysis below, we modify the linear Cournot model proposed by Salinger (1988) to allow for endogenous decisions on integration and cost-reducing investment by downstream firms. Note that the example is of purely introductory nature and will be generalized in Section 3.

2.1 The Set-up

Initially, there is full vertical separation with two upstream firms and two downstream firms. To produce one unit of the final product, downstream firms require one unit of the intermediate good provided by upstream firms. Before going into details, we give an overview of the time structure of the game (see Figure 1).

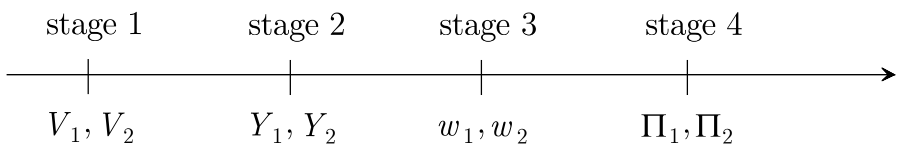

Figure 1: Time structure of the game

Overview. In stage 1, downstream firms simultaneously decide whether to integrate backwards by acquiring one of the upstream firms. The decision of firm $i = 1, 2$ is summarized in a variable V_i such that $V_i = 1$ if it integrates and $V_i = 0$ if it remains separated. In stage 2, downstream firms simultaneously carry out cost-reducing investments Y_i at cost $K(Y_i) = kY_i^2$, thereby determining the efficiency at which the intermediate good is transformed into the final product. In stage 3, any remaining separated upstream firms set wholesale prices or quantities for the downstream market, resulting in marginal costs $w_i \geq 0$ for obtaining the intermediate good. In stage 4, downstream firms compete à la Cournot in the product market. We now consider each of the four stages, in turn.

Stage 4. In the product market, firms face a linear inverse demand curve $P(Q) = a - Q$, with $Q = q_1 + q_2$ and $a > 0$. As will become clear below, the firms' activities in stages 1, 2 and 3 determine the marginal costs c_i of downstream firms in stage 4, where they obtain the profits $\Pi_i = (a - 2c_i + c_j)^2 / 9, i, j = 1, 2, j \neq i$.

Stage 3. Assuming that the marginal cost of producing the input is constant and normalized to zero, w_i is the marginal cost of producing the intermediate good for an integrated firm, and the equilibrium upstream price faced by a separated downstream firm. Depending on the integration decisions $\mathbf{V} = (V_1, V_2)$, this upstream price is either set directly by a single upstream firm or results from upstream competition between separated upstream firms in stage 3.[4] Obviously, stage 3 is irrelevant if both firms are vertically integrated: If $\mathbf{V} = (1, 1)$, the costs of obtaining the input are given exogenously as $w_i = 0, i = 1, 2$, by assumption. However, if $\mathbf{V} = (1, 0)$ or $\mathbf{V} = (0, 1)$, the remaining separated upstream firm sets the monopoly price for the separated downstream firm; only for the integrated firm is $w_i = 0$. If $\mathbf{V} = (0, 0)$, separated upstream firms compete à la Cournot.

Stage 2. In the investment stage, both firms initially have identical transformation costs $\bar{t}$. Denoting the efficiency improvement for the subgame $\mathbf{V}$ as $Y_i(\mathbf{V})$, ex post transformation costs are $t_i = \bar{t} - Y_i(\mathbf{V})$, and firm i's marginal costs are thus given by $c_i = w_i + t_i = w_i + \bar{t} - Y_i(\mathbf{V})$.

Stage 1. In the integration stage, downstream firms can acquire an upstream firm at fixed cost F. Let $w_i(\mathbf{V}, \mathbf{Y})$ denote the equilibrium choice of w_i in subgame $(\mathbf{V}, \mathbf{Y})$ and the resulting level of c_i as $c_i(\mathbf{V}, \mathbf{Y})$. Thus, downstream firms choose $V_i \in \{0, 1\}$ so as to maximize $\Pi_i(c_1(\mathbf{V}, \mathbf{Y}), c_2(\mathbf{V}, \mathbf{Y})) - V_i F$.

We now proceed to the subgame perfect equilibrium of the game.

2.2 Subgame Perfect Equilibrium

In the first three stages, the subgame perfect equilibrium gives rise to integration decisions $\mathbf{V}$, efficiency levels $Y_i(\mathbf{V})$ and input prices $w_i(\mathbf{V}, \mathbf{Y})$. As

[4] Like much of the related literature, we are abstracting in this example from the possibility that integrated firms also sell the intermediate input on the wholesale market. Our more general approach in Section 3 allows for such a possibility.

to stage 4, we use $Q_i(\mathbf{V}, \mathbf{Y})$ to denote downstream outputs for arbitrary integration vectors $\mathbf{V}$ and efficiency levels $\mathbf{Y}$, assuming that marginal downstream costs are $c_i(\mathbf{V}, \mathbf{Y}) = w_i(\mathbf{V}, \mathbf{Y}) + \bar{t} - Y_i(\mathbf{V})$. Similarly, we write the equilibrium mark-ups and profits of downstream firms as $M_i(\mathbf{V}, \mathbf{Y})$ and $\Pi_i(\mathbf{V}, \mathbf{Y})$, respectively.

Table 1 describes the subgame equilibrium for the three market configurations $\mathbf{V} = (0, 0)$, $\mathbf{V} = (1, 0)$ and $\mathbf{V} = (1, 1)$ and the associated reference configurations where firms are not allowed to invest (i.e. $\mathbf{Y} = (Y_1, Y_2) = (0, 0)$ by assumption). Equilibrium quantities are given as functions of the efficiency levels $\mathbf{Y}$ (and of k where appropriate). Throughout, $\alpha \equiv a - \bar{t}$ is a measure of market size. Table 2 summarizes the results for the special case $k = 1$.

We now highlight some properties of the linear Cournot example that will be useful for our more general analysis below.

<Tables 1 and 2 around here>

2.2.1 Investments Under Asymmetric Vertical Structure

First, we compare the investments of integrated and separated firms in the same market. Thus, we consider the asymmetric vertical market structure $\mathbf{V} = (1, 0)$. Figure 2a) depicts the optimal investment levels Y_1 and Y_2 as functions of the cost parameter k, fixing $\alpha = 1$. Figure 2b) shows the resulting market shares s_1 and $s_2 = 1 - s_1$, respectively. Clearly, the integrated firm 1 invests more and has a higher market share than the separated firm 2.

<Figure 2 around here>

To put the result into perspective, consider output decisions when firms are unable to invest into cost reduction (or equivalently, $k \to \infty$). Figure 2b) indicates that even when firms cannot invest into cost reduction, the market share of the integrated firm is higher than that of the separated firm, i.e. $s_1(Y_1 = 0, Y_2 = 0) > 0.5$. This reflects the simple fact that the integrated firm has lower marginal costs than the separated firm due to the elimination of a mark-up at the upstream level. However, this is not the end of the story: If firms can invest into cost reduction, the gap between the two firms widens, since the integrated firm invests more than the separated firm (see Figure 2b)). *Why* the integrated firm invests more than the separated firm is not quite as obvious. In Section 3, we will show that the intuition for this result becomes clearer in a more general model. We summarize our results for $\mathbf{V} = (1, 0)$ as follows:

Observation 1 *In the linear Cournot example with* $\mathbf{V} = (1, 0)$*, the integrated firm has higher output, mark-up and market share than the separated firm, even if efficiency levels are exogenous and identical. If investment levels are endogenous, the* ***integrated firm invests more*** *and the differences in outputs, mark-ups and market shares increase.*

2.2.2 Investments when Vertical Structure Changes

In Observation 1, we considered the investment behavior of integrated and separated firms for a fixed asymmetric vertical market structure $\mathbf{V} = (1, 0)$. This comparison was natural to understand the relation between integration and market share. However, it is also important to understand how *changes* in vertical structure affect the firms' investment behavior. Table 2 indicates that starting from $\mathbf{V} = (0, 0)$, firm 1's vertical integration increases own investment and decreases firm 2's investment.[5] Starting from $\mathbf{V} = (1, 0)$, firm 2's integration has similar effects on investments. The adverse effect on the competitor's investment is what we call the *intimidation effect* of vertical integration. We summarize these findings as follows:

Observation 2 *In the linear Cournot example, a firm's vertical integration increases its own investments and* ***decreases the competitor's investments (intimidation effect)****.*

2.2.3 Asymmetric Integration Equilibria

Next, we consider the subgame perfect equilibrium of the entire game. In particular, we show that there always exist suitable values of F such that

[5] More specifically, firm 1's investment increases by $\Delta Y_1 = 0.206\alpha$, whereas firm 2's investment decreases by $\Delta Y_2 = -0.117\alpha$.

vertical integration decisions are asymmetric. To this end, reconsider Table 2. For $k = 1$, this table lists the equilibrium profits for the subgames starting in stage 2, net of investment costs, $\Pi_i^*(\mathbf{V}) = \Pi_i(\mathbf{V}, \mathbf{Y}(\mathbf{V}))$. It is straightforward to calculate firm i's integration incentive $\Delta_i^*\Pi(V_j)$, which is the profit differential resulting from integration if the competitor's integration status is V_j. The table shows that

$$\Delta_1^*\Pi(0) \equiv \Pi_1^*(1,0) - \Pi_1^*(0,0) = 0.214\alpha^2;$$
$$\Delta_1^*\Pi(1) \equiv \Pi_1^*(1,1) - \Pi_1^*(0,1) = 0.089\alpha^2.$$

Thus, we immediately obtain our first result for the linear Cournot example.

Result 1 *In the linear Cournot example, the subgame perfect equilibrium involves* ***asymmetric vertical integration*** *for suitable levels of fixed acquisition costs* $(0.214\alpha^2 \geq F \geq 0.089\alpha^2)$.

We now show that cost-reducing investments are important for explaining asymmetric vertical integration. To this end, we consider a setting where firms are not allowed to invest into cost-reduction. We define

$$\Delta_1^{NI}\Pi(V_2) \equiv \Pi_1(1, V_2; \mathbf{0}) - \Pi_1(0, V_2; \mathbf{0}),$$

and similarly for $\Delta_2^{NI}\Pi(V_1)$, where the superscript indicates "No Investment". Table 2 shows that

$$\Delta_i^{NI}\Pi(0) = 0.133\alpha^2 < \Delta_1^*\Pi(0); \quad \Delta_i^{NI}\Pi(1) = 0.083\alpha^2 < \Delta_1^*\Pi(1).$$

Therefore, asymmetric integration is also possible without the investment stage; however, the relevant interval is much smaller $(0.133\alpha^2 \geq F \geq 0.083\alpha^2)$. Compared with a game without investments, integration incentives are higher if firms can make cost-reducing investments, and this effect is much more pronounced when competitors are separated. We thus obtain the second result for the Cournot example.

Result 2 *In the linear Cournot example, the subgame perfect equilibrium involves asymmetric vertical integration for a* ***larger range of parameters*** *than for a reference game without investment.*

Result 2 is our main result for the Cournot example. It highlights the links between integration and investment decisions and relates to the intimidation effect of integration identified in Observation 2. Apparently, a firm that faces a separated competitor gains more from influencing investment decisions by vertical integration than a firm that faces an integrated competitor. Thereby, the strategic substitutes property of integration decisions—which holds that a competitor's decision to integrate decreases own integration incentives—becomes more pronounced.

We now proceed to a more general framework to improve our understanding of this mechanism.

3 A Reduced Form Model

In this section, we show how the results from Section 2 generalize beyond the linear Cournot model and clarify the intuition behind these results. To do so, we adopt an analytical framework similar to Buehler and Schmutzler (2005). However, here we add another stage to the game where downstream firms decide endogenously about cost-reducing investment.

3.1 Assumptions

Rather than explicitly considering all four stages of the game (as in the Cournot example), we now focus on stages 1 and 2; stages 3 and 4 are treated in reduced form. We still assume that, initially, there are two identical separated downstream firms. However, we now allow that there are $s \geq 2$ identical separated upstream firms.

Recall that in stage 1, downstream firms simultaneously decide whether to take over one of the upstream suppliers, ($V_i = 1$ if they do, $V_i = 0$ otherwise, $i = 1, 2$). We suppose that the acquisition costs are given by a constant $F > 0$. In stage 2, firms choose cost-reducing investments. We now assume that reducing costs by Y_i involves investment costs of $K_i(Y_i)$, which are increasing in Y_i. To model stages 3 and 4 in reduced form, we make the following assumptions.

Assumption 1 *The firms' decisions in stages 1 and 2 result in unique input prices,* $w_i(\mathbf{V},\mathbf{Y}), i = 1,2$. *Therefore, marginal costs are*

$$c_i(\mathbf{V},\mathbf{Y}) = w_i(\mathbf{V},\mathbf{Y}) + \bar{t} - Y_i.$$

For given marginal costs $c_i, i = 1,2$, downstream competition must satisfy the next assumption.

Assumption 2 *For every cost vector* $\mathbf{c} = (c_1, c_2)$, *there exists a unique product market equilibrium resulting in outputs* $q_i(\mathbf{c})$, *prices* $p_i(\mathbf{c})$, *mark-ups* $m_i(\mathbf{c}) = p_i(\mathbf{c}) - c_i$, *and profits* $\pi_i(\mathbf{c})$, *respectively, such that*

$$\pi_i(\mathbf{c}) = q_i(\mathbf{c}) \cdot m_i(\mathbf{c}).$$

The functions $q_i(\mathbf{c})$, $m_i(\mathbf{c})$ *and thus* $\pi_i(\mathbf{c})$ *are non-increasing in* c_i *and non-decreasing in* c_j.

Assumption 2 holds for many standard oligopoly models. Using Assumption 2, equilibrium product market profits Π_i as well as mark-ups M_i and outputs Q_i are functions of the firms' vertical structures and efficiency levels:

Notation 1 *For* $i = 1,2$, $j \neq i$, *we denote equilibrium downstream profits, mark-ups and quantities, respectively, as*

$$\Pi_i(\mathbf{V},\mathbf{Y}) = \pi_i(c_1(\mathbf{V},\mathbf{Y}), c_2(\mathbf{V},\mathbf{Y})); \quad (1)$$

$$M_i(\mathbf{V},\mathbf{Y}) = m_i(c_1(\mathbf{V},\mathbf{Y}), c_2(\mathbf{V},\mathbf{Y})); \quad (2)$$

$$Q_i(\mathbf{V},\mathbf{Y}) = q_i(c_1(\mathbf{V},\mathbf{Y}), c_2(\mathbf{V},\mathbf{Y})). \quad (3)$$

We require that profits satisfy the following symmetry condition, which obviously holds in the Cournot case.

Assumption 3 *Product market profits are exchangeable, i.e. for all* $V', V'' \in \{0,1\}$ *and* $Y', Y'' \in [0,\infty)$,

$$\Pi_1(V', V'', Y', Y'') = \Pi_2(V'', V', Y'', Y').$$

Our next assumption is crucial. It states relations between vertical structure and outputs and mark-ups, respectively, which are satisfied in the linear Cournot model.

Assumption 4 *The firms' mark-ups and outputs satisfy the following conditions:*

(i) $M_1(1,0;\mathbf{Y}) > M_1(0,1;\mathbf{Y})\,; Q_1(1,0;\mathbf{Y}) > Q_1(0,1;\mathbf{Y})$

(ii) $M_2(0,1;\mathbf{Y}) > M_2(1,0;\mathbf{Y})\,; Q_2(0,1;\mathbf{Y}) > Q_2(1,0;\mathbf{Y})$

Assumption 4 compares the mark-ups and outputs of an integrated firm facing a separated competitor with those of a separated firm facing an integrated competitor. Part (i) can be justified by reference to (2) and (3), which show that an increase in V_1 and a decrease in V_2 will affect Q_1 and M_1 via c_1 and c_2. More specifically, starting from $\mathbf{V} = (0,1)$, suppose firm 1 integrates, resulting in $\mathbf{V} = (1,1)$. Our earlier discussion suggests that this reduces c_1 by eliminating the upstream mark-up or benefiting from technical efficiencies. As firm 2 is integrated and therefore supplies itself with the intermediate good, there is no effect on firm 2's cost. The only effect of moving from $\mathbf{V} = (0,1)$ to $\mathbf{V} = (1,1)$ on firm 1's mark-up and output is thus a reduction of firm 1's marginal cost, which should be unambiguously positive. Next, compare $\mathbf{V} = (1,1)$ and $\mathbf{V} = (1,0)$. Arguing as before, the costs of firm 1 should be unaffected and firm 2's costs should increase. If firm 1's mark-up and output are increasing in the competitor's costs, they should therefore increase. Combining the two steps, we get part (i) of Assumption 4. The argument for part (ii) is analogous.

Our last assumption concerns the effect of higher efficiency on own and competitor mark-up and output, respectively.

Assumption 5 *M_i and Q_i are both increasing in Y_i and decreasing in Y_j.*

Assumption 5 states that an increase in own efficiency increases own mark-up and output, and conversely for an increase in competitor efficiency. The first part of the assumption is natural if higher efficiency does not only decrease own costs, but also (weakly) increases the wholesale price, so that competitor costs increase. If, however, higher efficiency decreases the wholesale price, competitor cost reductions could, in principle, outweigh the positive effect of higher efficiency on own costs. The second part of the assumption can be justified with similar arguments.

3.2 Relation to the Literature

Our reduced form set-up is motivated by various more specific models. In particular, our crucial Assumption 4 is consistent with several models of successive oligopolies, in which efficiency and/or foreclosure effects of vertical integration have been identified.

For example, Salinger (1988) treats vertical integration decisions as exogenous. He considers a fixed-proportion linear Cournot model with arbitrary numbers of homogeneous firms. It turns out that integration always causes an efficiency effect as it eliminates successive mark-ups. Whether integration also generates a foreclosure effect depends on parameter values. Nevertheless, Assumption 4 is always satisfied in Salinger's model. Analogous statements hold for the modified Cournot model analyzed by Gaudet and van Long (1996), where integrated firms purchase from the upstream market to increase rivals costs, and integration decisions are endogenous.

Ordover et al. (1990) examine a fixed-proportion model with endogenous integration decisions. Two upstream firms produce a homogenous input good and compete in prices. In one version of their model, two downstream firms produce differentiated products and compete in prices. Their model thus rules out an efficiency effect of integration when the competitor is not integrated.[6] Similarly, there is a foreclosure effect only when the competitor is not integrated.

Hart and Tirole (1990) analyze different variants of a model where two upstream firms produce a homogenous input good and compete in prices, whereas two downstream firms engage in Cournot competition.[7] Non-linear

[6] Because of Bertrand competition upstream, there is an upstream (monopoly) mark-up only when there is an integrated competitor.

[7] These variants differ with respect to the bargaining power pertaining to upstream and downstream firms.

contracts between upstream and downstream firms are allowed. In the so-called ex post monopolization variant of the model, the more efficient upstream firm integrates with one of the downstream firms and slightly undercuts the less efficient upstream firm to supply the other downstream firm. This results in an efficiency effect of integration. Integration has no foreclosure effect, as it does not raise the downstream rival's costs.

Chen (2001) examines a fixed-proportion model where two or more upstream firms produce a homogenous input good and may have different marginal costs, and two downstream firms produce differentiated final products and compete in prices. This author also identifies an efficiency effect and, depending on parameters, a foreclosure effect.

Buehler and Schmutzler (2005) provide a reduced-form analysis of competition in successive oligopoly. They examine the causes of asymmetric vertical integration and discuss the relation between a firm's efficiency and its integration incentive. They view the existence of a combined positive own effect and adverse cross effect as the essential property of vertical integration.

Summing up, previous literature suggests that vertical integration is likely to help gaining competitive advantage by cutting own costs or by raising rivals' costs.

3.3 Properties of Profit Functions

We now derive useful properties of the profit function $\Pi_i(\mathbf{V},\mathbf{Y})$. More specifically, in Lemma 1 we show how investment incentives $\partial\Pi_i/\partial Y_i$ depend on $\mathbf{V}$ and $\mathbf{Y}$.

Lemma 1 (profit function properties) *Suppose Assumptions 1-5 are satisfied.*

(i) Suppose that, in addition,

$$\frac{\partial Q_1}{\partial Y_1}(1,0;\mathbf{Y}) \geq \frac{\partial Q_1}{\partial Y_1}(0,1;\mathbf{Y}); \quad \frac{\partial M_1}{\partial Y_1}(1,0;\mathbf{Y}) \geq \frac{\partial M_1}{\partial Y_1}(0,1;\mathbf{Y}). \quad (4)$$

Then

$$\frac{\partial \Pi_1}{\partial Y_1}(1,0;\mathbf{Y}) > \frac{\partial \Pi_1}{\partial Y_1}(0,1;\mathbf{Y}). \quad (5)$$

(ii) Suppose that, in addition,

$$\frac{\partial^2 Q_1}{\partial Y_1 \partial Y_2} \leq 0; \quad \frac{\partial^2 M_1}{\partial Y_1 \partial Y_2} \leq 0. \tag{6}$$

Then

$$\partial \Pi_i / \partial Y_i \text{ is non-increasing in } Y_j \text{ for } j \neq i,\ i,j = 1,2 \tag{7}$$

(iii) Suppose that, in addition,

$$\frac{\partial Q_i}{\partial Y_i}, \frac{\partial M_i}{\partial Y_i} \text{ are non-decreasing in } V_i \text{ and non-increasing in } V_j. \tag{8}$$

Then

$$\frac{\partial \Pi_i}{\partial Y_i} \text{ is non-decreasing in } V_i \text{ and non-increasing in } V_j. \tag{9}$$

Proof. See Appendix. ■

Let us consider each part of Lemma 1, in turn.

Part (i) gives conditions for investment incentives to be higher for an integrated firm facing a separated competitor than for a separated firm facing an integrated competitor. The intuition relies on Assumption 4 which says that both mark-up and demand are higher for an integrated firm facing a separated competitor than for a separated firm facing an integrated competitor. Since higher mark-up means that demand increases resulting from greater efficiency are more valuable, and higher demand means that mark-up increases are more valuable, the benefits from vertical integration and cost-reducing investment tend to reinforce each other. Put differently, there are *demand/mark-up complementarities* in product market competition. As a result, an integrated firm with high mark-up typically finds it more beneficial to invest into cost reduction than a separated competitor.

There is, however, a potential countervailing effect: The size of the demand and mark-up increases associated with higher efficiency could, in principle, decrease with vertical integration. The additional conditions on $\partial Q_i / \partial Y_i$ and $\partial M_i / \partial Y_i$ exclude this possibility. We think these conditions are fairly natural, as higher downstream efficiency tends to increase the input price due to higher demand (see Banerjee an Lin 2003), which, in turn, reduces the output and mark-up increases resulting from higher transformation efficiency for a separated firm. This effect is clearly absent for an integrated firm, at least if it does not buy from the input market. Further note that the conditions on $\partial Q_i/\partial Y_i$ and $\partial M_i/\partial Y_i$ are stronger than necessary. All we require is that the demand/mark-up complementarities in the product market dominate over any negative effect of vertical integration on $\partial Q_i/\partial Y_i$ and $\partial M_i/\partial Y_i$.

Part (ii) gives conditions for investment incentives to decrease when competitors become more efficient. Intuitively, the changes of variables under consideration (increases in Y_i and decreases in Y_j, respectively) lead to increases in firm i's demand and mark-up which are mutually reinforcing. Again, there might be countereffects of Y_i and Y_j on $\partial Q_i/\partial Y_i$ and $\partial M_i/\partial Y_j$ that could upset the results. The additional conditions on the second partial derivatives of Q_i and M_i exclude this possibility.[8]

Part (iii) is closely related to part (i). Note that (8) is more restrictive than (4). Using this more restrictive condition leads to a stronger implication: (9) implies (5), but not vice versa.

With these properties of the profit functions in place, we now proceed to study the firms' investment and integration decisions in the second and the first stage of the game, respectively.

3.4 Analyzing Cost-Reducing Investments

Consider the second stage of the game in which firms take simultaneous decisions on cost-reducing investment. The first result generalizes Observation 1, showing how the investments of integrated and separated firms differ.

Proposition 1 *Consider the subgame starting in stage 2. Suppose that, in addition to Assumptions 1-5, (4) and (6) are satisfied. Then, the* ***integrated firm invests more*** *into cost reduction than the separated firm, i.e. if $V_k = 1$ and $V_\ell = 0$, then $Y_k > Y_\ell$.*

[8] In the linear Cournot example, these additional conditions are satisfied (see Table 1).

Proof. See Appendix. ∎

Proposition 1 states that, if the firms differ only with respect to their vertical integration status, the integrated firm will invest more into cost reduction than the separated firm. Intuitively, by Assumption 4, the integrated firm has higher equilibrium demand and mark-up than its competitor. The demand/mark-up complementarity therefore implies that the integrated firm has higher incentives to invest than the separated competitor, as reflected in (5). In addition, condition (7) implies that the higher investment of the integrated firm and the lower investment of the competitor are mutually reinforcing. Thus, integrated firms should invest more than separated firms.

To sum up, the observation that integrated firms tend to invest more into cost reduction than separated firms should be expected to hold quite generally, as it only requires fairly natural assumptions on product market competition. Proposition 1 is consistent with the observation that integrated firms tend to have high market shares: Not only does integration have a direct efficiency effect which works towards higher market shares, but integrated firms also tend to invest more into cost reduction.[9]

We now generalize Observation 2 and study the effect of a firm's vertical integration on both firms' investments. This involves a comparison of the firms' investments under *different* market structures, whereas Proposition 1 was based on a comparison of investments within a *given* asymmetric vertical market structure.

Proposition 2 *Suppose that, in addition to Assumptions 1-5, conditions (6) and (8) hold. Then the equilibrium level of Y_i is non-decreasing in V_i and non-increasing in V_j.*

Proof. Apply Lemma 1 and Milgrom and Roberts (1990, Theorem 5). ∎

Intuitively, by (9), if one firm integrates, this increases its own investment incentive, whereas it decreases the competitor's investment incentive. Recall that the negative effect on the competitor's investment incentive is the *intimidation effect* of vertical integration. By (7), the positive effect on own

[9]Proposition 1 generalizes to more than two firms. The proof uses similar techniques as the special case of two firms.

investment and the (negative) on the competitor's investment are mutually reinforcing.

As argued in the justification of (6), there may be countereffects because the size of the increases in output and mark-up resulting from integration may depend on the efficiency levels as well. Also, as already noted, the required condition (8) is less general than the corresponding condition (4) for Proposition 1: Condition (8) implies condition (4), but the converse statement is not true.[10] Nevertheless, Proposition 2 indicates that under fairly natural assumptions, the finding that a firm's vertical integration increases own investment and decreases competitor investment generalizes beyond the linear Cournot model.

3.5 Analyzing Integration Decisions

We now consider endogenous integration decisions in stage 1, accounting for the induced effects on cost-reducing investment. To this end, we introduce the following notation:

Notation 2 *For* $f = \Pi, Q, M$,

(i) let

$$f_i^*(\mathbf{V}) \equiv f_i(\mathbf{V}, \mathbf{Y}(\mathbf{V})), \quad i = 1, 2,$$

describe equilibrium profits, outputs and mark-ups, respectively, as functions of integration decisions (evaluated at the equilibrium choices of cost-reducing investment).

(ii) let

$$\Delta f_1^*(\mathbf{V}_2) \equiv f_1^*(1, \mathbf{V}_2) - f_1^*(0, \mathbf{V}_2); \quad \Delta f_2^*(\mathbf{V}_1) \equiv f_2^*(\mathbf{V}_1, 1) - f_2^*(\mathbf{V}_1, 0)$$

denote the effect of vertical integration on equilibrium profits, outputs and mark-ups, respectively, taking induced effects on efficiency levels into account.

[10] Also, generalization of Proposition 2 to more than two firms requires additional conditions.

We introduce the following additional assumption.

Assumption 6 *The firms' equilibrium* ***mark-ups*** *and* ***outputs*** *satisfy the following conditions:*

(i) $M_i^*(\mathbf{V})$ *and* $Q_i^*(\mathbf{V})$ *are non-decreasing in* V_i.

(ii) $M_i^*(\mathbf{V})$ *and* $Q_i^*(\mathbf{V})$ *are non-increasing in* V_j.

Assumption 6 holds in our linear Cournot example (see Table 2 for the special case $k = 1$). To understand why the assumption is plausible, recall that $\mathbf{V}$ affects mark-ups and outputs both directly and indirectly, that is, via $\mathbf{Y}(\mathbf{V})$. Intuitively, the direct effects already lend some plausibility to assumption 6, but indirect effects via $\mathbf{Y}(\mathbf{V})$ reinforce them.

More specifically, consider condition (i): If V_i decreases c_i, this should support a direct positive effect on $M_i^*(\mathbf{V})$ and $Q_i^*(\mathbf{V})$. Also, V_i affects c_j by the impact on the wholesale price. If the wholesale price increases, the marginal costs of a non-integrated firm j go up, and the wholesale price effect will thus reinforce the direct efficiency effect.[11] Importantly, there also is an indirect intimidation effect of integration: As argued before, vertical integration tends to reduce a competitor's incentive to invest into efficiency improvement, strengthening the direct positive effect of own integration on output and mark-up.

Condition (ii) can be justified in a similar way: First, as firm j's integration reduces its marginal costs, firm j becomes a stronger downstream competitor, which reduces $M_i^*(\mathbf{V})$ and $Q_i^*(\mathbf{V})$ by way of downstream interaction. Second, after integration, the integrated upstream firm may have an incentive to curtail supply to the input market, raising the costs of a non-integrated rival by way of upstream interaction. This is the foreclosure effect of vertical integration. Again, crucially, these direct effects are reinforced by the indirect intimidation effect of vertical integration.

[11] Whether such vertical foreclosure emerges in equilibrium depends on subtle details of the specific model under consideration: For instance, foreclosure will typically occur for low numbers of upstream suppliers (Salinger 1988) or high costs of switching suppliers (Chen 2001).

Note that Assumption 6 holds in our linear Cournot model, even though the direct effect of V_j on $M_i^*(\mathbf{V})$ and $Q_i^*(\mathbf{V})$ will typically have the wrong sign for given $\mathbf{Y}$. This illustrates that the intimidation effect of integration may well dominate the direct effect. Put differently, cost-reducing downstream investment makes the existence of demand/mark-up complementarities in the product market even more likely than without investment.

Next, we (i) give conditions under which vertical integration decisions are strategic substitutes (Proposition 3), and (ii) show that there will thus be asymmetric equilibria where one firm integrates and the other stays separated (Proposition 4). These results are related to Lemma 1 and Proposition 1 in Buehler and Schmutzler (2005), where we abstracted from endogenous cost-reducing investment, though.

Proposition 3 (strategic substitutes) *Suppose Assumptions 1-6 hold. Further assume that the following statement holds for $i, j = 1, 2, i \neq j$:*

$$\Delta Q_i^*(V_j) \text{ and } \Delta M_i^*(V_j) \text{ are non-increasing in } V_j. \tag{10}$$

Then vertical integration decisions are strategic substitutes, i.e.

$$\Delta \Pi_i^*(0) \geq \Delta \Pi_i^*(1) \quad \text{for } i = 1, 2. \tag{11}$$

Proof. By exchangeability, it suffices to consider firm 1's incentive to integrate, $\Delta \Pi_1^*(V_2)$. Rewriting this profit differential yields

$$\begin{aligned} \Delta \Pi_1^*(V_2) = {} & Q_1^*(1, V_2) \cdot \Delta M_1^*(V_2) \\ & + M_1^*(0, V_2) \cdot \Delta Q_1^*(V_2). \end{aligned} \tag{12}$$

By Assumption 6(i), both $\Delta M_1^*(V_2)$ and $\Delta Q_1^*(V_2)$ are non-negative. By Assumption 6(ii), $Q_1^*(1, V_2)$ and $M_1^*(0, V_2)$ are both non-increasing in V_2. By (10), $\Delta M_1^*(V_2)$ and $\Delta Q_1^*(V_2)$ are non-increasing in V_2. Thus (12) is non-increasing in V_2. ■

The intuition for the strategic substitutes property relies on the monotonicity of M_i^* and Q_i^* in the integration variables. As we argued, this is likely to be more pronounced than the corresponding property for M_i and Q_i, which would justify strategic substitutes. Therefore, the observation from the Cournot example that asymmetric integration arises for a larger parameter interval when cost reductions are considered is not a coincidence.

Proposition 3 immediately implies that there may be asymmetric equilibria where one firm integrates and the other remains separated, even if firms start out identically and face the same exogenous integration costs.

Proposition 4 (asymmetric equilibria) *Suppose the conditions of Proposition 3 are satisfied, i.e. vertical integration decisions are strategic substitutes. Then, for suitable values of F, there exist equilibria where exactly one firm integrates* ($\Delta\Pi_i^*(0) \geq F \geq \Delta\Pi_i^*(1)$).

Proof. If integration decisions are strategic substitutes, we must have $\Delta\Pi_i^*(0) \geq F \geq \Delta\Pi_i^*(1)$ for suitable values of F. ■

Intuitively, Proposition 4 states that, if vertical integration decisions are strategic substitutes, then there must be levels of acquisition costs where integration is profitable for only one of the firms.

Propositions 3 and 4 together give a very intuitive rationale why asymmetric vertical integration equilibria might emerge. However, there are two *caveats*. First, the strategic substitutes condition may be violated if there is a strong foreclosure effect, as firm i will then have relatively high (low) costs when it is separated (integrated, respectively). Thus, firm i's cost reduction from integration is likely to be higher when firm j is integrated. If integration decisions are strategic complements rather than substitutes, vertical integration by firm j renders vertical integration more profitable for firm i (i.e. $\Delta\Pi_i^*(1; \mathbf{Y}) > \Delta\Pi_i^*(0; \mathbf{Y})$). As a result, only symmetric equilibria can exist: Either both firms integrate or none. Second, even if integration decisions are strategic substitutes, symmetric equilibria will still arise when F is so high that $F > \Delta\Pi_i^*(0)$: Then, no firm will integrate. Similarly, when F is so low that $F < \Delta\Pi_i^*(1)$, all firms integrate.

4 Conclusions

We have examined the interplay of endogenous vertical integration and cost-reducing downstream investment in a model of successive oligopoly. Our main findings are the following:

First, vertical integration tends to increase (decrease) the integrating firm's (competitor's) investment incentive. We call the adverse effect on the competitor's investment incentive the *intimidation effect* of vertical integration. The effect is economically relevant in the sense that it may well dominate the direct effect of integration on the firms' outputs and mark-ups. The intimidation effect of vertical integration implies that there is a strategic incentive to integrate. In particular, vertical integration may serve as a top dog strategy, tapering the competitor's cost-reducing investment.

Second, the strategic integration incentive is likely to be larger for a firm facing a separated (rather than integrated) competitor. Therefore, asymmetric equilibria typically involve *large integrated firms and small separated firms*. This is in line with the market structure of a number of industries discussed in the literature.

Third, our analysis suggests an intuitive explanation for the initial difference between a *(vertically integrated) leader* and a *(vertically separated) laggard* in an investment game potentially leading to endogenous market dominance.

Appendix

Proof of Lemma 1

(i) Differentiating firm 1's profit function yields

$$\frac{\partial \Pi_1}{\partial Y_1} = \frac{\partial Q_1}{\partial Y_1} M_1 + \frac{\partial M_1}{\partial Y_1} Q_1.$$

Using Assumption 5, all terms on the r.h.s. of this equation are positive, and both $M_1(1,0;\mathbf{Y}) > M_1(0,1;\mathbf{Y})$ and $Q_1(1,0;\mathbf{Y}) > Q_1(0,1;\mathbf{Y})$. (5) thus follows immediately from

$$\frac{\partial Q_1}{\partial Y_1}(1,0;\mathbf{Y}) \geq \frac{\partial Q_1}{\partial Y_1}(0,1;\mathbf{Y}) \text{ and } \frac{\partial M_1}{\partial Y_1}(1,0;(\mathbf{Y})) \geq \frac{\partial M_1}{\partial Y_1}(0,1;\mathbf{Y}).$$

(ii) Using

$$\frac{\partial^2 Q_1}{\partial Y_1 \partial Y_2} \leq 0, \frac{\partial^2 M_1}{\partial Y_1 \partial Y_2} \leq 0,$$

arguments similar to those used in the proof of (i) show that $\partial^2\Pi_1/\partial Y_1\partial Y_2 \leq 0$. (7) thus follows immediately.

(iii) is analogous.

Proof of Proposition 1

(i) By (5) and exchangeability (Assumption 3), we have

$$\frac{\partial \Pi_2}{\partial Y_2}(0,1;Y) = \frac{\partial \Pi_1}{\partial Y_1}(1,0;\mathbf{Y}) > \frac{\partial \Pi_1}{\partial Y_1}(0,1;\mathbf{Y}) = \frac{\partial \Pi_2}{\partial Y_2}(1,0;\mathbf{Y}). \tag{13}$$

Now, define $\theta = (V_1, V_2)$ and $x_1 = Y_1, x_2 = -Y_2$. Thus, consider the game with objective function

$$f_i(x_1, x_2; \theta) = \Pi_i(\theta; x_1, -x_2) - K_i(|x_i|).$$

By (7), this game is supermodular.[12] By (5), changing θ from $(0,1)$ to $(1,0)$ increases $\partial\Pi_1/\partial Y_1$ and reduces $\partial\Pi_2/\partial Y_2$. In other words, Π_i has increasing differences in (θ, x). Thus, the result follows from Theorem 5 in Milgrom and Roberts (1990).

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[12] See Milgrom and Roberts (1990) for the concept of supermodular games.

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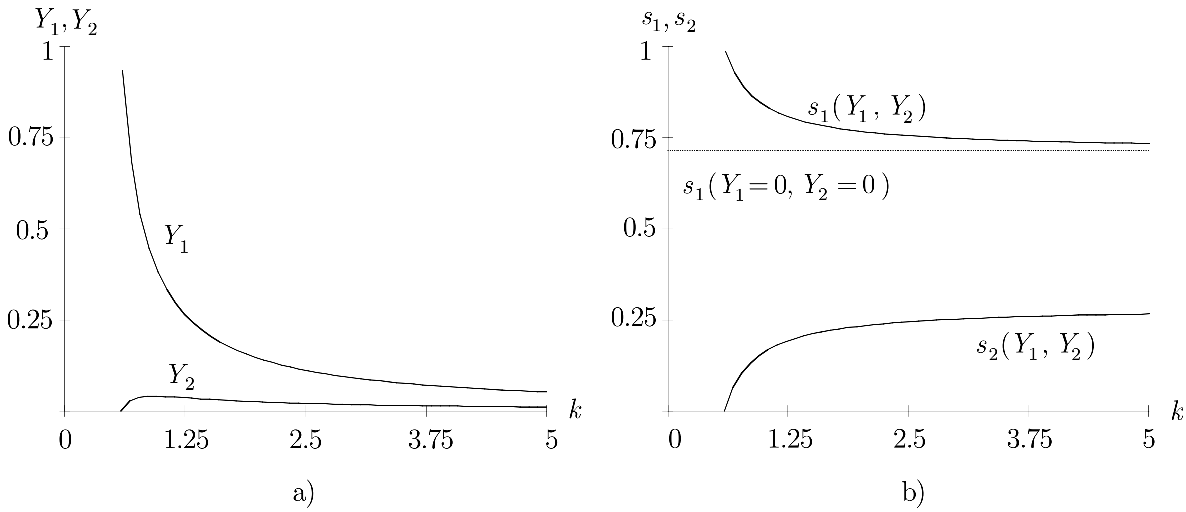

Figure 2: Investments and market shares in the linear Cournot model ($\alpha = 1$).

Table 1: The linear Cournot example

	$\mathbf{V}=(0,0)$		$\mathbf{V}=(1,0)$		$\mathbf{V}=(1,1)$	
	$\mathbf{Y}=(Y_1(\mathbf{V}),Y_2(\mathbf{V}))$	$\mathbf{Y}=(0,0)$	$\mathbf{Y}=(Y_1(\mathbf{V}),Y_2(\mathbf{V}))$	$\mathbf{Y}=(0,0)$	$\mathbf{Y}=(Y_1(\mathbf{V}),Y_2(\mathbf{V}))$	$\mathbf{Y}=(0,0)$
$w_1(\mathbf{V},\mathbf{Y})$	$\frac{2\alpha+Y_1+Y_2}{6}$	$\frac{\alpha}{3}$	0	0	0	0
$w_2(\mathbf{V},\mathbf{Y})$	$\frac{2\alpha+Y_1+Y_2}{6}$	$\frac{\alpha}{3}$	$\frac{\alpha-Y_1+2Y_2}{4}$	$\frac{\alpha}{4}$	0	0
$M_1(\cdot)=Q_1(\cdot)$	$\frac{4\alpha+11Y_1-7Y_2}{18}$	$\frac{2\alpha}{9}$	$\frac{5\alpha+7Y_1-2Y_2}{12}$	$\frac{5\alpha}{12}$	$\frac{4\alpha+8Y_1-4Y_2}{12}$	$\frac{\alpha}{3}$
$M_2(\cdot)=Q_2(\cdot)$	$\frac{4\alpha-7Y_1+11Y_2}{18}$	$\frac{2\alpha}{9}$	$\frac{2\alpha-2Y_1+4Y_2}{12}$	$\frac{\alpha}{6}$	$\frac{4\alpha-4Y_1+8Y_2}{12}$	$\frac{\alpha}{3}$
$\Pi_1(\mathbf{V},Y)$	$\frac{(4\alpha+11Y_1-7Y_2)^2}{324}-kY_1^2$	$\frac{4\alpha^2}{81}$	$\frac{(5\alpha+7Y_1-2Y_2)^2}{144}-kY_1^2$	$\frac{25\alpha^2}{144}$	$\frac{(4\alpha+8Y_1-4Y_2)^2}{144}-kY_1^2$	$\frac{\alpha^2}{9}$
$\Pi_2(\mathbf{V},Y)$	$\frac{(4\alpha-7Y_1+11Y_2)^2}{324}-kY_2^2$	$\frac{4\alpha^2}{81}$	$\frac{(2\alpha-2Y_1+4Y_2)^2}{144}-kY_2^2$	$\frac{4\alpha^2}{144}$	$\frac{(4\alpha-4Y_1+8Y_2)^2}{144}-kY_2^2$	$\frac{\alpha^2}{9}$
$Y_1(\mathbf{V})$	$\frac{11\alpha}{81k-11}\Big\vert_{k=1}=\frac{11}{70}\alpha$	0	$\frac{-14\alpha+105\alpha k}{432k^2-195k+14}$	0	$\frac{2\alpha}{9k-2}$	0
$Y_2(\mathbf{V})$	$\frac{11\alpha}{81k-11}$	0	$\frac{-14\alpha+24\alpha k}{432k^2-195k+14}$	0	$\frac{2\alpha}{9k-2}$	0

Table 2: The linear Cournot example with $k = 1$

	$\mathbf{V} = (0,0)$		$\mathbf{V} = (1,0)$		$\mathbf{V} = (1,1)$	
	$\mathbf{Y} = (Y_1(\mathbf{V}), Y_2(\mathbf{V}))$	$\mathbf{Y} = (0,0)$	$\mathbf{Y} = (Y_1(\mathbf{V}), Y_2(\mathbf{V}))$	$\mathbf{Y} = (0,0)$	$\mathbf{Y} = (Y_1(\mathbf{V}), Y_2(\mathbf{V}))$	$\mathbf{Y} = (0,0)$
$w_1(\mathbf{V}, \mathbf{Y})$	0.386α	$\frac{\alpha}{3}$	0	0	0	0
$w_2(\mathbf{V}, \mathbf{Y})$	0.386α	$\frac{\alpha}{3}$	0.179α	$\frac{\alpha}{4}$	0	0
$M_1(\cdot) = Q_1(\cdot)$	0.257α	$\frac{2\alpha}{9}$	0.622α	$\frac{5\alpha}{12}$	0.429α	$\frac{\alpha}{3}$
$M_2(\cdot) = Q_3(\cdot)$	0.257α	$\frac{2\alpha}{9}$	0.120α	$\frac{\alpha}{6}$	0.429α	$\frac{\alpha}{3}$
$\Pi_1(\mathbf{V}, \mathbf{Y})$	$0.041\alpha^2$	$0.049\alpha^2$	$0.255\alpha^2$	$0.174\alpha^2$	$0.102\alpha^2$	$\frac{\alpha^2}{9}$
$\Pi_2(\mathbf{V}, \mathbf{Y})$	$0.041\alpha^2$	$0.049\alpha^2$	$0.013\alpha^2$	$0.028\alpha^2$	$0.102\alpha^2$	$\frac{\alpha^2}{9}$
$Y_1(\mathbf{V})$	0.157α	0	0.363α	0	0.286α	0
$Y_2(\mathbf{V})$	0.157α	0	0.040α	0	0.286α	0

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