Vertical integration under external shocks

A theoretical approach

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1 Introduction

Positioning into an industry by either specialising or integrating the supply chain is one of the toughest choices a manager can make and should not be taken lightly. For that numerous researches contributed to answering this question — whether or not vertically integrate — either from a theoretical or empirical point of view. Though no clear answer has been made for now as many parameters enter into account. However, one should agree with Stuckey and White (1993)'s idea that "*companies should change their vertical integration strategies when market structures change. The structural factors most likely to change are the number of buyers and sellers and the importance of specialized assets*". Nonetheless, literature also agrees to the fact that other determinants are at stake such as avoiding the double marginalisation problem (Tirole, 1988; Duram, 2000; Belleflamme, 2014) or avoiding excessive transaction costs due to market incomplete information (Williamson, 1979; Rosen, 1988; Perry, 1989; Carlton and Perloff, 1994). Still, there should not be one aspect prevailing on the others. Moreover, decisions to integrate are usually firm- and industry-specific (Barrera-Rey, 1995), making it more complex to provide a clear answer.

However, even if many parameters are at stake, we aim to provide a new theoretical approach about how market structure influences vertical integration with respect to uncertainties that surround upstream and downstream production costs. This comes from the understanding that production costs are changing (i.e. they are not constant across time) and seem to respond to different external variables. For instance, it is common that agriculture production costs differ across regions but also across years because of different weather conditions. This additional concept should then go further in the analysis of market structure because it assumes that firms should take into account the likelihood of shocks when they decide to enter new production stages. Yet, "*shocks include deregulation, changes in input costs, and innovations in financing technology that induce or enable alterations in industry structure*" (Mitchell and Mulherin, 1995). Here we mainly focus on shocks that change input costs or production costs. This analysis should provide evidence that external shocks could foster or dampen integration decision according to the market structure in the industry. It could also bring back information about why one notices more integration in some industries — such as in the oil industry — as compared to others.

We structure this research paper as follow: we firstly define integration as well as its main advantages and downsides. We outline the most common points of the literature that are the externality and the costs based approaches. In addition to these two points, the literature also exhibits several other determinants favouring integration but also bring up a few disadvantages. Secondly, we advance

the idea that in an uncertain world, firms are impacted by shocks that can either strike part of or all the supply chain. We point out that these shocks mostly depend on specific production process that a firm can choose but also on unpredictable variables appearing to different locations. Thirdly, we develop two theoretical models that encompass several assumptions and hypotheses about integration. Comparing these two models would help us to contrast two similar industries' patterns (e.g. with the same number of upstream and downstream firms) except that one of them involves integration and the other not. Fourthly, we expand and analyse these two models according to the three hypotheses we made (i.e. market size affects incentive to vertically integrate, when all the industry is moving towards integration, integration is more profitable and external shocks can provide incentives to vertically integrate). Fifthly, we discuss the assumption that integrated firms might deal with external suppliers/manufacturers in case of new products implementations or excessive external shocks. This part alleviates one of our assumptions that was integrated firms do not use external suppliers/manufacturers as it is usually detrimental for them.

Our results show that vertical integration acts a way to be protected against shocks by recouping part of the margin in the tier that does not suffer from it. However, integrated firms bear the risk of facing shocks on each level of the supply chain while contracts can prevent against prices increase. Still, we determine that dealing with different contracts (i.e. ex-ante or spot) can shift the incentive to integrate with respect to uncertainty (either from an upstream or downstream firms point of view). For instance, according to Mahoney (1989), *A downstream firm has the incentive to purchase one or more upstream firms because this improves its pricing forecast and thus its ability to purchase the appropriate level of capital*. We also figure out that — for similar characteristics — industries that encompass on average higher production costs have more interest to integrate than ones that benefit from cheaper production costs. Furthermore, as stated by "*Salinger (1988), it is especially in the presence of increasing average cost that the integrated firms can have sometimes interest to take part in the intermediate market*" (Dufeu, 2004). Moreover, the presence of shocks can induce scale diseconomies when part of the integrated firm becomes not able to fit the production level of the other part. "*The fact that scale requirements differ among vertically linked activities suggests that integrated businesses must either operate on a scale large enough to satisfy the requirements of the most volume-dependent production stages or suffer the penalties of operating on inefficient scales at one or more stages*" (Buzzell, 1983). Uncertainty will then add new aspects on why should firms need to integrate or not with regard to their industry pattern. Despite all this, determine exactly the point wherein firms should considering integration is tricky as it depends from numerous factors.

2 Vertical Integration

A firm is generally considered as vertically integrated when it embodies the entire stages of production. The firm controls then the entire production process which gives it complete ownership and managerial control. One could point out two ways of being vertically integrated: "*A firm can either integrates backward or forward by building, respectively, its own manufacturing plant or its own distribution facilities or by acquiring productive assets from a firm that already participates in a relevant upstream or downstream market*" (Riordan, 2005). A less restrictive approach still considers vertical integration when the firm encompasses only a part of the production stage. This case is described as "partial vertical integration" because the integrated firm does not cover the entire production process and must, at some point, depend on other suppliers or other buyers. Partial vertical integration also refers, in the literature, to the term "tapered integration".

Vertical integration is typically present in either new industry (because it facilitates technological adoption) or either an industry in decline (because market becomes less efficient) (Stuckey and White, 1993). While disintegration typically appears when the industry is growing.

2.1 Why do firms integrate?

The literature expresses several determinants of vertical integration, but two points of view stand out: an externality based approach and a cost based approach. On the one hand, the in-house production costs can be lower than the market price. This results from inefficiency and successive markup mirrored by the double marginalisation problem (Tirole, 1988; Duram, 2000; Belleflamme, 2014). On the other hand, transaction costs — due to market incomplete information — lead to excessive contracting costs as to avoid some opportunistic behaviours from contractors (Williamson, 1979; Rosen, 1988; Perry, 1989; Carlton and Perloff, 1994).

Next to that, some interests are given to ensure a steady input supply (White, 1971; Carlton, 1979; Liberman, 1991), to increase ex-post firm performance (Mahoney, 1989; Grant, 1996; Novak and Stern, 2008; Forbes and Lederman, 2010) or to adapt to innovative change (Langlois, 1988; Nickerson and Silverman, 2003).Yet, there is no proof that one effect prevails on the others. Each incentive depends on the structure of the industry or on its specificity.

Another way to see why do firms vertically integrate is that the vertically integrated firm profit represents the maximal aggregated profit. The more the aggregated profit is located far away from the expected profit of the integrated firm, the more integration becomes attractive.

Although positive costs advantages appear with vertical integration, organisation costs increase with the firm size. Vertical integration of successive tiers could hinder the advantage of avoiding double marginalisation problem or of avoiding excessive transaction costs as it becomes too complex to manage with all the production stages. Adding to that, Carlton (1979) argues that "*vertical integration can be regarded as a means of transferring risk from one sector of the economy to another*". Contrary to Carlton who depicts vertical integration as a way to avoid uncertainty, Thesmar and Thoening (2007) react by stating that *any exogenous increase in vertical separation amplifies the impact of demand shocks on the product and labor markets by increasing firm-level volatility of sales and employment*.

Whether integration is profitable or not depends then of myriad of factors and thus mostly on firm characteristics (e.g. production cost, specialisation, new innovative product,...) and industries characteristics (e.g. upstream/downstream competition, oligopolistic market,...). It seems that the decision of being integrated or not may turn out to be firm-specific even within the same industry (Barrera-Rey, 1995).

2.1.1 Escape from the double marginalisation problem

The main objective of vertical integration is to avoid the double marginalisation problem which emerges when firms do not coordinate their decisions and fix higher margins than their production costs. The problem appears under vertical separation and with incomplete information about production costs of the other part of the supply chain. As stated by Durham (2000), "*Each time the downstream firm takes any action to increase the quantity it sells (i.e. lowers price, increases promotional effort), the upstream firm's profit is increased. However, the downstream firm does not take this into account when it makes its decision and therefore tends to restrict quantity relative to the vertically integrated solution*". It results that each firm on both levels of the supply chain produces below the optimal quantity which causes, in fine, lower profit. Though, the double marginalisation problem is less significant when competition is increasing because firms can not hold superior margin when they lose market power.

Take the upstream and downstream price (respectively P_u and P_d) from the two-stage chain supply market we analyse in section 3.2. When the number of downstream firms (n_d) and/or the number of upstream firms (n_u) increase, the price tends to reach its marginal production cost.

$$P_d = \frac{(n_d + n_u + 1)a_d + n_u C_d + n_d C_u}{(n_d + 1)(n_u + 1)} \geq c_d + P_u$$

$$P_u = \frac{a_d - n_d^{-1} C_d + C_u}{(n_u + 1)} \geq c_u$$

One other way to interpret the marginalisation problem is to look at market power through the Lerner Index. The Lerner Index (L) defines the ability to price above the perfectly competitive level (i.e. above production costs). "*It is defined as the markup, that is, the difference between price (P) and marginal costs (C) as a percentage of the price*" (Belleflamme, 2014). An index close to 1 mirrors a highly concentrated market with high market power whereas an index close to 0 reflects a perfect competitive market.

$$L = \frac{P - C}{P}$$

The Lerner Index analysis allows us to point out couple of results. First, it confirms the decrease in impact of the double marginalisation problem when competition increases. Second, it displays that the upstream market seems to have influence on the downstream market (i.e. the Lerner Index of the downstream market is more affected by the increase in competition than the upstream's one). The upstream market can therefore appropriate a larger margin than the downstream market, all other things being equal.

Nonetheless, in an imperfect market without information problem, non-linear pricing (i.e. when the price paid is not proportional to the quantity sold) or two-part tariff can solve the double marginalisation problem (Belleflamme, 2014).

2.1.2 Avoid transaction costs

"*Some firms are not vertically integrated but buy from a small number of suppliers or sell through a small number of distributors. These firms often write complex contracts that restrict the actions of those with whom they deal*" (Carlton and Perloff, 1994). The transaction costs represent costs linked to those intermediary-market product transactions. Zhou (2016) argues that vertical integration helps to coordinate the upstream and downstream part of the firm by calibrating the incentives, reducing opportunist behaviour and favouring information sharing along the supply chain. According to Langlois (1988), when there are no additional costs except production costs, each firm would try to take advantage of the competitive market and no vertical integration would appear. Still, "*the level of vertical integration we observe in the economy largely reflects a minimum of the sum of production*

and transaction costs" (Langlois, 1988). Note that vertical integration becomes more beneficial as the transaction costs increase (Carlton and Perloff, 1994). On the other hand, Mahoney (1989) also assumes that when transaction costs are small, long-term contracts can achieve similar outcome than vertical integration. One can articulate transaction costs between four categories.

The first one takes into account specific asset that could induce opportunist behaviour. According to Williamson (1979), the degree of transaction-specificity plays a key role in transaction costs. At some point, when a firm relies too much on another firm, it might be the victim of harmful behaviours such as higher prices. The concept mirrors the dependency on specific assets — due to investments that enclosed the firm to one buyer or seller — or the additional cost of changing of contractors (e.g. due to additional transportation costs). The additional transportation costs issue mainly appears with site specificity. The fixed asset such as a mine needs to be located closely to the manufacturers to avoid excessive costs. At some point, specific assets are related to sunk costs. Rosen (1988) states that shared investment costs should lead to contract enforcement as to avoid opportunistic behaviour on later return. On the other side, if the industry relies only on unspecialised assets, firms can overcome opportunism by changing their suppliers. Nonetheless, one could claim that using unspecialised assets can lead to less production efficiency or more homogeneous product.

The second one refers to uncertainty. In Business to Business contracts, firms can not monitor the effective production costs of their contractors; that can lead to overrated price. This is enforced when a part of the industry faces negative shocks because firms can claim to have higher costs even if not, as to extract higher profit. It facilitates opportunist behaviour and requires then to increase the frequency of transaction renewals. Moreover, it is very costly for a firm to distinguish opportunistic from nonopportunistic behaviour ex-ante (Williamson, 1981). Furthermore, uncertainty makes it also more difficult to define long-term contracts which must establish all requirements and obligations for all states of nature (Perry, 1989). With a high level of uncertainty, firms are better off producing in house (Stuckey and White, 1993).

The third one relies on information transfer. Information is generally considered as scarce as markets can not depict perfect information (Malmgren, 1961). On the one hand, because firms in the supply chain face interdependency (e.g. final demand affects production in the upstream tier), they can join their mutual information to maximise their understanding of the market (e.g. on consumer preferences). Firms benefit then from sharing information at each tier but do not always have the motivation to do so (because of the competitive effect of other firms at each tier). On the other hand, boundaries and/or exclusivity contract should be settled to ensure that information would not be sold

or used to other competitors. Malmgren (1961) explains this idea by the cost of information collection, and also by the fact that "*information is not equally distributed among all possible productive units*".

The fourth one is linked to coordination. It can be easier to manage centralised operations than to face multiple individual decisions. Coordination is even more relevant when transaction-specificity is high because it already needs closely partnership or when technological constraints (i.e. complementary activities) are present (e.g. in the steel industry, it would be more expensive to delay inputs supply because of the cost of reheat the raw material into the blast furnace). However, coordination needs to be planned between contractors which induces additional transaction costs. For example, organise a "just in time" production to avoid storage costs or inefficiency costs needs additional operating contracts as to avoid default from the supplier and ensure a constant supply. Coordination is also correlated with information transfer as it allows a better understanding of the market that facilitates the cooperation between firms.

2.1.3 Ensure the input supply

One other key point of vertical integration emerges from the need to ensure a steady input flow. Usually, input supply should not be a problem when it is present in a competitive market. But de facto, markets reflect additional externalities that should not have been present in theory. For example, substitutability is not always easily achievable. Whithe (1971) depicts the situation where "*Kaiser-Frazer contracted with Continental Motors in 1946 to supply it with engines. The relation was entirely unsatisfactory and in the end Kaiser had to take over the engine plant*". Chandler (1964) states that "*the need for assured supplies demanded increasing vertical integration*". Moreover, delivery issues might reflect information transfer problem that is by-passed by integration. Carlton and Perloff (1994) state that "*it is often easier to exchange information within a firm than between firms*".

Carlton (1979) models the problematic of input supply with a two-stage model that includes a random demand (for the intermediate or final good) and ex-ante production decision. He explains two situations, either the final demand or the demand for intermediary goods is lower than expected. Firstly, when final demand is lower than expected, the total quantity produced might not be entirely sold. The equilibrium price should then take into account this uncertainty (i.e. the price in an uncertain market must always exceed its costs, since it is necessary that price not only cover per unit production costs, but also production costs of unsold goods). Secondly, when the demand for intermediary goods does not match the expected production of the upstream market, upstream producers face unsold products. "*By producing the input for itself, the stage 1 firm bears the risk of the unsold input, while when the stage 1 firms relies on the factor market for the input, it is the stage 2 who*

bear this risk" (Carlton, 1979). Aside that, Carlton reveals that because of the variability of input demand that could drive up the inputs' price, integration could be an alternative to avoid these extra costs. According to White (1971) who studied the Automotive industry, "*a way of reducing the risks of vertical integration is through partial or tapered integration: a company can produce a portion of its needs of an item and buy the fluctuating remainder*".

Liberman (1991) empirically tests the model of Carlton, using data on 34 organic chemical products' producers. His results are consistent with Carlton, and support that firms integrate to avoid input variability. Next to that, he points out that whether or not a firm chooses to integrate mostly depends on the proportion of the input in its total production cost. "*If the input constitutes a minor proportion of total costs, even a large relative price premium paid to its supplier will have little effect on the profits of the firm*" (Liberman, 1991).

2.1.4 Increase firm performance

Another question that might arise when we try to understand vertical integration is the following: Do vertically integrated firms perform better than those that don't?

Novak and Stern (2008) suggest, after investigating the Luxury Automobile Industry, that "*Outsourcing a function constrains a firm's ability to adapt to unforeseen contingencies or benefit from learning and the experience associated with that function*". They balance the trade-off between rapid access to production with outsourcing and develop an internal production allowing to benefit from learning effect and better flexibility. According to them, market-based interaction concedes high performance in the early stage of production — because the firm is able to access to the best technology available — but does not allow ex-post improvement (e.g. with consumer feedback correction). It is mainly due to the uncertainty that surrounds any product life-cycle and that cannot be precisely defined by contract. They conclude that "*Luxury automakers face a dynamic governance tradeoff: while outsourcing may yield a higher level of initial performance, vertical integration facilitates improvements over the product lifecycle*" (Novak and Stern, 2008). Grant (1996) states that "*knowledge aquisition requires greater specialization than if needed for its utilization*". It would confirm the assumption of Noval and Stern that learning effect would prevail, over the outsourcing approach, at some point of the product's life-cycle. Mahoney (1989) also asserts that forward integration can ensure to a manufacturer quality through the production chain.

Forbes and Lederman (2010) analyse the Airline Industry in the US. They find that vertical integration might give a performance advantage by facilitating adaptation decision due to weather conditions

or congestion issues. For the Airline Industry, firm performance would reflect operational improvements, rather than specialisation improvements.

2.1.5 Adapt to innovative change

Langlois (1988) extends the willingness to adopt a new technological feature as an incentive to vertically integrate. He puts forward the flexibility of internal organisation as a way to adapt to new innovations as compared to a competitive market. "*The decentralisation of markets makes it difficult to coordinate a complex reorientation of production in the face of change*" (Langlois, 1988). Moreover, Belleflamme (2014) divides innovation into two situations: when innovation is drastic (i.e. giving a monopoly position in the industry) and when it is non-drastic (i.e. decreasing the production cost but without cancelling competition). It appears that non-drastic innovation that does not change the core of the production process would not affect the incentive to integrate. However, "*an innovation that is sufficiently radical will require significant changes elsewhere in the system*" (Langlois, 1988), as to fully benefit from the competitive advantage. Drastic innovations in a non vertically integrated industry would then induce specific investment from one part of the supply chain, leading to transaction-specificity and then to potential opportunist behaviours as stated by Williamson (1979). Nickerson and Silverman (2003) also discuss the case of innovative change by stating that long-term contracts hinder the ability to change the structure of production. "*Formal contractual commitments constrain an organization from switching to an alternative trading partner or organizational form until the contract expires*" (Nickerson and Silverman, 2003). Vertical integration can then by-pass the adaptation issue due to the new technology.

Acemoglu et al. (2010) investigate the impact of technology intensity as a determinant of vertical integration from a theoretical point of view as well as from an empirical one. They emphasise the holdup problem that could appear with technology investment. They follow the idea of Grossman and Hart (1986) stating that contractual right can be divided into two categories: specific rights that are defined by contract and residual rights that are unspecified and could lead to opportunist behaviour. At some point, "*when it is costly to list all specific rights over assets in the contract, it may be optimal to let one party purchase all residual right*" (Grossman and Hart, 1986). Acemoglu et al. (2010) find a divergence from the impact of technology intensity on the incentive to vertically integrate, at the supplying tier and at the producing tier. Their analyses, of 77 manufacturing industries, show that "*vertical integration in a pair of industries is less likely when the supplying industry is more technology intensive and the producing industry is less technology intensive*" (Acemoglu et al., 2010). They also attribute the share of inputs into the total production cost as an incentive to vertically integrate. They assert that a high degree of supply input would foster the gain of integrating its supplier.

2.2 Costs of vertical integration

As previously expressed, besides the positive advantages of integration, some disadvantages can appear. There are mainly due to different scale requirements that make vertical integration inefficient as compared to a competitive market or due to organisation costs that are increasing with the integrated firm size. One could also mention the lack of flexibility that induces higher sunk costs in case of technology shift.

Firstly, with costs asymmetries or with different production levels between upstream and downstream firms, vertical integration can lead to costs disadvantages as compared to firms competing in the intermediary market (i.e. non integrated firms). For instance, a downstream firm can backward integrate with an upstream firm that is not the most effective one and then produces at a more expensive price than with a more effective suppliers or at a non optimal scale (i.e. if the downstream and upstream component of the integrated firm do not benefit from the same production scale). "*The fact that scale requirements differ among vertically linked activities suggests that integrated businesses must either operate on a scale large enough to satisfy the requirements of the most volume-dependent production stages or suffer the penalties of operating on inefficient scales at one or more stages*" (Buzzell, 1983). Note that scale diseconomies do not represent an issue if the integrated firm also interacts with external suppliers/manufacturers (cf. section 6).

Secondly, Barrera-Rey (1995) states that "*a very important component of the costs of growing large is linked to managerial diseconomies*". Because managerial abilities are usually scarce (i.e. managers face diminishing returns), vertical integration induces extra costs to maintain control over all the production stage. Barrera-Rey (1995) argues that managerial diseconomies are closely related to control.

Thirdly, Mahoney (1989) points out that vertical integration could generate higher sunk costs as vertically integrated firms are usually producing specialised assets linked to their in-house production process. Notice that vertical integration is usually put forward because it allows specialising the production process. However, "*if technology or market changes make the products or methods of one stage in a vertically integrated system obsolete, the integrated company may find adjusting very difficult*" (Buzzell, 1983).

Nonetheless, costs of vertical integration — as well as gains from integration — depend on market structure, firms characteristics, etc. Therefore, even within the same industry, some firms can benefit from integration while some others can suffer from it.

2.3 Theory of Uncertainty

Subsequent to these determinants of vertical integration, one aspect has been neglected in the literature: the impact of costs uncertainty on the incentive to vertically integrate. Though uncertainty in intermediary and final goods' demand were evaluated by Carlton (1979) and Thesmar and Thoenig (2007), they did not express the trade-off appearing with production costs variations.

In an uncertain world, inputs production costs can not be constant, and thus fluctuate independently from the willingness of the firm (e.g. according to weather condition for the agriculture industry). We delimit the approach of uncertainty by the impact of shocks that could influence any industry. In that theoretical approach, we distinguish two kinds of shock that influence production costs:

First, the structural shocks. Because each firm could follow a specific production process, their production costs will react differently according to any shocks. By choosing its technological process, a firm tends to be more or less impacted by some unexpected aleas. For example, a gas powered plant won't suffer from coal price increase. The technological process is then linked, at a certain extent, to some inputs considerations (e.g. a cheap input with a high probability of default or an expensive input but constant in time). There is then no reason to believe that one shock should affect the entire industry. Still, some cyclical shocks can impact the industry as a whole or a big part of it. Next to that, it is possible that firms chose the same technological process as it reflects the best alternative. The tier will then face the same negative effect of the shock.

Second, the exogenous shocks. These shocks do not depend on the technological process chosen by the firm but are unpredictable variables, such as weather, that influence production costs. This is mostly the case in agricultural industry. Since crops are located in different areas, they will not suffer from the same weather conditions, even when they have same characteristics. Specific yield should then be applied to every plant. But shocks such as global warming can still affect the entire industry (or at least alter a larger area). However, one could argue that some exogenous shocks should appear more or less frequently in some regions due to intrinsic characteristics (such as topology). It would then partially remove the costs uncertainty assumption. Nonetheless, it seems pretty unlikely that these shocks follow a perfect pattern and would become predictable. Note that this exogenous shocks approach can also be assimilated to non agricultural sectors. For instance, a flood can result in a loss/deterioration of stored assets or a fire that strokes out in a petrochemical industry would require to stop the infrastructure for safety reasons.

2.3.1 Should demand uncertainty foster or dampen vertical integration?

In the literature, two models try to explain why uncertainty in demand can either foster (Carlton, 1979) or dampen (Thesmar and Thoenig, 2007) vertical integration (cf. subsubsection 2.1.3). Each of these two models asserts the following arguments:

On the one hand, Carlton (1979) assumes that producing in-house (i.e. be vertically integrated) allows to be secured from inputs demand variability and thereby to avoid driving up inputs prices. Vertical integration becomes one mechanism to escape the costs that someone else's variability of demand imposes on the market.

On the other hand, in a competitive market, ex-post production shocks are costly as the markup of the firm decreases with competition (Thesmar and Thoenig, 2007). Because the firm cannot transfer the loss on its margin, it losses more than in an oligopolistic market. This hypothesis is inconsistent with our model as the more concentrate the market is, the more the expected loss from an external shock is prominent.

2.3.2 Structural shocks approach

We now depict the structural shocks approach with the case of industrial manufacturers. In the literature, firms within industries are, most of the time and by simplicity, characterised by equivalent production costs. However, this assumption does not reflect prevailing situation (i.e. that firms largely face different production costs). One way to explain production costs differentiation is by assuming that each firm follows specific production processes. Another approach points out countries specific regulations (e.g. minimal wage, specific corporate tax, import duties, etc.) that leverage production costs.

On the one hand, firms choose technological processes according to different criteria that depend either on inputs availability, production costs related to the technological process, new breakthrough innovation, etc. Production costs will then react differently according to any shocks related to any inputs required to the production process. However, firms are also limited to an adaptive technological level (i.e. old firms are usually stuck with old technologies or limited by the structural change they can pursue while new firms entering the market can benefit from more effective technologies). This concept encompasses the differences between the conception from scratch ("*Greenfield project*") that benefits from lower production costs but with higher fixed costs and existing plants with higher production costs but lower fixed costs.

On the other hand, firms structure can be impacted by countries specific regulations. At first glance, these regulations should impact firm's production costs in the same way but it generally depends on the structure of the firm (e.g. its size, its localisation, etc.). However, they are independent from the willingness of the firm.

Nonetheless, we mainly focus on the first approach that links production costs asymmetry to different technological processes. As already stated, technological processes would partly explain why firms are not equally affected by the same external shocks. Take for instance an energetic choice — between using either gas or coal — that firms can make. At first sight, these two energy alternatives should not intervene in the core technological process of the firm but variation in energy price will impact production costs. To illustrate this concept, we analyse the sugar industry as a all (i.e. gathering sugar from sugar beet and sugar cane). Sugar industry tends to be related at some extent to technological choices according to what inputs the firm chooses to deal with. Without taking into account localisation restriction, sugar can be produced by two ways — from sugar beet or from sugar cane — but its production process differs from one of these two inputs. "*Not surprisingly, diverse agro-climatic conditions and differences in the technological levels of the agricultural sector in different countries result in wide variations in agricultural yields*" (FO Lichts, 2018).

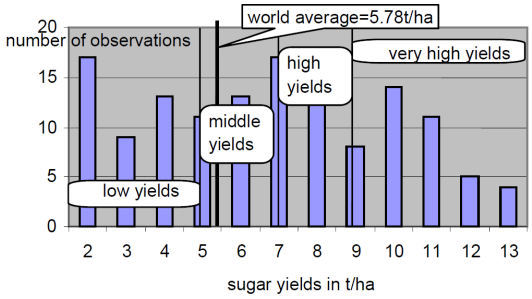

Figure 1: Frequency distribution of sugar beet yields (2000/1-2002/03) and producers grouping by relative efficiency.
Source: ISO (2005).

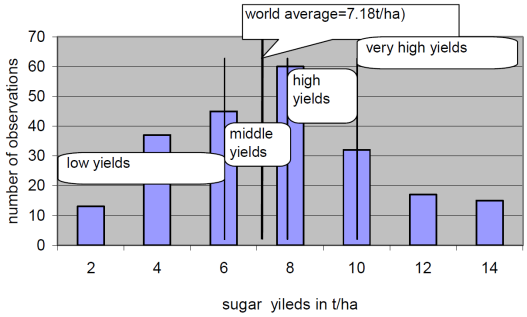

Figure 2: Frequency distribution of sugar cane yields (2000/1-2002/03) and producers grouping by relative efficiency.
Source: ISO (2005).

Roughly, raw sugar is produced by crushing sugar cane into bagasse (the residual part of the cane) and cane juice. The cane juice is then heated up by burning the bagasse to evaporate the water and produce raw sugar. In the same vein, white sugar is produced by diffusing beets into hot water in the opposite direction. It results in raw juices that need to evaporate its water and crystallise to obtain white sugar. While sugar beet refineries are usually big structures, "*sugar cane mills varying from small-scale single farms to multiple-unit managements (including large cooperatives and vertically integrates estates)*" (FO Lichts, 2018). Therefore, technological processes can vary according to the mill size (between more traditional or industrial structures). Though sugar beet refineries are more or less the same, their technological level varies according to their construction date (i.e. they are usually old structures that were partly improved). Sugar production hints the following findings. Firstly, the technological process is linked to input consideration and leads to more or less capital intensive industry. As compared to the raw sugar production, white sugar is considered as capital intensive because it encompasses expensive technologies that are improving across time. Secondly, on average, choosing between raw sugar or white sugar production will imply same external shocks issues because technological processes are based on the same patterns (i.e. there are only non-drastic innovations).

Figure 3: World Average Sugar Yields for Cane and Beet (t/ha).
Source: FO Lichts (2018).

Figures 1 and 2 refer to the yield distribution for both beet (left panel) and cane (right panel) between 2000/01 and 2002/03 whereas figure 3 focuses on the world average yield. Sugar yield reflects the sugar production per harvested hectare and takes into account both sugar content of the input and technological process to extract that sugar. The International Sugar Organization (2005) attributes huge variation between countries for both sugar beet yield and sugar cane yield to agriculture improvements but also to industrial improvements. According to FO Lichts (2018), "*agricultural and industrial yields in the cane's sector (in terms of world averages) have been nearly stagnated while beet*

sugar yields increase can be attributed to remarkable improvements in both agricultural and industrial yields achieved by the sector" (cf. Figure 3).

We stated that countries specific regulations could also impact production costs. We introduce the case of the European regulation that imposed production quota to the European sugar industry as an example. In 2006, the European Commission introduces a sugar regulation that establishes a limited production for each member states. This resulted in the closure of the least efficient factories. On the one hand, it had a positive effect on production capacities but on the other hand, it increased transportation costs of each plant (due to the increase in average supply distance between the beet growers and the sugar refineries).

2.3.3 Exogenous shocks approach

To illustrate the exogenous shocks approach, we develop the case of agricultural goods. Firstly, unpredictable variables such as weather, diseases or insects largely impact agricultural productions (i.e. their yields or harvested areas). Nonetheless, they influence crop production in different ways (i.e. they affect yield and harvested area differently). Yield is defined as the amount of agricultural output (in tonne) per unit of land (ha) while harvested area represents the total space allocated to one crop. Lizumi and Ramankutty (2015) state the following example to denote this ambivalence: "*Let us say a landslide associated with a tropical cyclone occurs and a portion of cropland is buried in dirt; in this case harvested area would decrease, but yield in the harvested area would not necessarily decrease. In another extreme case, an unfavourable growing-season climate, would lower yield, but not necessarily decrease harvest area*". Furuya and Kobayashi (2009) assert that yield variations with respect to temperature also vary between crops and localisation (i.e. countries or regions level). However, Gobin (2010), who modelled Belgian crops yields between 1940 and 2010, states that "*crops often respond nonlinearly to changes in their growing conditions and have threshold responses*". On average, small or brief weather modifications would then be insignificant. Secondly, variations in yield or harvested area induce a fluctuation in production costs.

We establish an overview of the European sugar beet sector between 2014 and 2018 to picture these disparities (Table 1). Table 1 exhibits the sugar beet yield variations according to average national data. FO Lichts (2018) states that "*different natural conditions and levels of development of national agricultural and industrial sectors result in great variations in agricultural yields (beet production per harvested hectare)*". Hoofmann et al. (2009) also associate these high variations in yield and quality of sugar beet across Europeans regions to climatic conditions. But besides high disparities among EU countries, variations within countries appear. For instance, according to the CBB rapport of 2016/17,

Belgium that usually benefits from high sugar beet yield (i.e. 80t/ha) suffered from unfavourable weather condition during 2016/2017 campaign that lowered yield to less than 70t/ha. It was mainly due to disruption in the sowing period due to rainfall, high temperature and high level of rain during June. In the case of sugar beet, four main weather conditions impact its yield. First, excessive rainfall during the sowing period which delays the sowing period and therefore reduces the time of cultivation. Second, lack of sunshine or extreme precipitation during the growing period. Third, rainy harvest period that affects the amount of soil tare. Fourth, early frosts during the late harvest period that reduce the sugar content of the beet.

Country	2017/18	2016/17	2015/16	2014/15
Austria	75	80	62.6	83.7
Belgium	80	68.2	82.3	86.6
Croatia	65	70	54.5	63.5
Czech Rep	65	65	60.9	70.2
Denmark	65	65	66.6	70.3
Finland	35	36.8	32.7	45.7
France	87	83.4	87	92.9
Germany	74	75	71	79.8
Greece	60	57.9	51.9	63.9
Hungary	64.2	65	58.8	69.2
Italy	63	66	57	72.8
Lithuania	60	60	68	59.6
Netherlands	84	83.3	83.3	90.8
Poland	65	66.5	54.6	68.2
Portugal	62	61.6	57.6	37.6
Romania	42	42	41	44.7
Slovakia	70	71.4	57.2	69.8
Spain	90	87.1	93.3	96.9
Sweden	70	64.9	60.8	59.7
United Kingdom	69.5	66.1	69	80

Table 1: Sugar beet yield in Mt per Hectare
Source: FAS/USEU based on data from FAS offices in EU MS and FAO.

Table 1 also indicates that yield decreases do not affect EU countries at the same time or with the same intensity such that it implicitly indicates divergences in weather condition between EU members. This suggests that exogenous shocks can spare some farms while it can be detrimental for others, even if they are located closely to another. This is even more relevant when farms benefit from different characteristics such as topology (i.e. altitude and soil composition). Besides, crops are also damaged by diseases or insects that are specific to some regions. For example, "*beet yellows virus could induce possible yield losses of 6 to 60% due to multiple factors, the most important of which is the time of infection and the atmospheric pressure*" (Manderyck, 2018). The Beet yellows virus is mainly located in Belgium, North of France and South England. It requires therefore additional production costs (i.e. the use of neonicotinoid pesticides) to avoid contamination.

3 Models and Hypothesis

To understand how shocks could foster or dampen integration, we develop two models depicting a two stage supply chain (i.e. with an upstream and a downstream market) that allows confronting a model without integration with a second model that encompasses vertical integration. Comparing these two models should — for equivalent situation — determine the incentives to vertically integrate (related to the potential profit available) with respect to shocks. These two models are both based on a Cournot competition (i.e. firms compete with quantity) with costs asymmetry, linear market demand and illustrate the case of a "one-to-one conversion" whereas one final output of production requires one input. For simplicity, all algebra will be denoted with an underscore letter "d" or "u" for, respectively, downstream and upstream market. Note that the concept of uncertainty is absent from these two models and will be added thereafter for computation simplicity.

Though we are aware that modelling a successive supply chain with and without integration does not constitute an innovation in the field of industrial organisation. Adding the concept of external shocks — mirrored by production costs variations — should be regarded as an innovative point of view as compared to the existing literature. To do so, we state three assumptions that highlight key concepts and represent the core of the development. Each of them will be developed in subsection 3.1.

Assumption 1. *Firms can face inherent shocks according to their technological process and/or exogenous and unpredictable shocks related to their location.*

Assumption 2. *Integrated firms do not benefit from buying or selling to other competitive firms (either in the downstream or upstream market).*

Assumption 3. *Firms can choose different types of contract that will prevent them from shocks.*

These three assumptions emphasise how external shocks are defined, why we do not choose to allow market interactions when firms are vertically integrated and why firms could use different types of contract when they deal with each others (i.e. ex-ante or spot contract). Firstly, we state that shocks are represented by marginal costs increase for the firms concerned and happen with some probability. Secondly, we consider that vertically integrated firms do not have any interest to interact with external suppliers/manufacturers as they already benefit from cheaper input price. And thirdly, contracts can be determined ex-ante or at the current market price.

Afterwards, we adjust the core models by changing some parameters such as the number of upstream firms or the number of integrated firms to reflect different aspects of an industry. The interpretation of theses variances will be furnished in the following two sections (i.e. Vertical Oligopoly Market and Full Integrated Market) that contain 3 cases. They will consist to specifically analyse the impact of market size (either in the downstream or upstream market) and the impact of being integrated when all the industry is moving towards integration. These three cases support the following hypothesis:

Hypothesis 1. *Market size (either in the downstream or upstream market) affects incentive to vertically integrate.*

When part of the supply chain becomes competitive, integration should be less rewarding. This reflects the idea that in oligopolistic, market marginal production costs are below the market price. Integration could then solve this double marginalisation problem but becomes less effective when marginal production costs are close to market price.

Hypothesis 2. *When all the industry is moving towards integration, integration is more profitable than market competition.*

Because we assume that integrated firms do not interact with external suppliers or manufacturers, integration acts as a barrier to entry and concentrate the market. Non integrated downstream firms are then buying their inputs at a higher price than before. While non integrated upstream firms are selling less inputs in the downstream market.

Hypothesis 3. *External shocks can provide incentives to vertically integrate.*

Because integration cancels the double marginalisation problem, integrated firms can compensate a loss in their upstream or downstream component. This effect should be less present with market size either upstream or downstream.

Additionally to the three cases, we discuss about integration with external suppliers/manufacturers. This case specifies some advantages of market when firms are integrated and provide some conditions without which we should not observe interaction among the integrated firms and the other suppliers or manufacturers. It provides some clues about when assumption 2 could be invalidated.

Note that in these three cases as well as in the discussion about integration with external suppliers/manufacturers, we firstly discuss the gain from integration within a certainty point of view and secondly add the impact of uncertainty. Moreover, we provide, for each of these variances, examples mirroring a specific industry.

3.1 Assumptions

3.1.1 Assumption 1: External shock assumption

We firstly state that marginal production costs might fluctuate — between each plant (i) and between each tier (t) — according to the probability of facing an external shock.

$$c^*_{i,t} = \lambda_t(c_{i,t} + s_t) + (1 - \lambda_t)(c_{i,t})$$

where $c^*_{i,t}$ is the new marginal production cost in upstream or downstream tier, $c_{i,t}$ is the marginal production cost if no shock happens, s_t is the negative effect of the shock and λ_t the probability that a shock happens. We also distinguish the negative effect of the shock and the probability that the shock happens according to each tier. Note that we do not analyse the impact of positive shocks because if the integrated firm benefits from integration despite the negative shock, it must be true that it also benefits while a positive shock happens.

We model an industry with n asymmetric firms as it allows us to state the following assumption: "Even if in fine marginal production costs are similar between firms, asymmetry releases the constraint that every firm follows the same technological process". As explained in subsection 2.3, we distinguish two kinds of external shocks: structural shocks and exogenous shocks. Each firm could then face inherent shocks according to their technological process and/or exogenous and unpredictable shocks related to their location. Note that we assume that shocks are observable and well known from other players. For instance, information about weather issues are easy to find, even at a small level.

3.1.2 Assumption 2: Integration with no external suppliers/manufacturers

We also consider that there is no interaction between the integrated firm and any external suppliers/ manufacturers for the following reasons. Firstly, by buying on the market, the downstream component of the integrated firm loses its cost-advantage — as it was previously buying its inputs at marginal cost. It should be correct till the double-marginalisation persists (i.e. when $c_{u,I} \leq P_u$). Secondly, by selling on the upstream market, the upstream component of the integrated market induces a lower wholesale price as it increases the total quantity produced on the upstream market (that could be detrimental for the downstream component of the integrated firm). We can still interpret what would happen if the integrated firm would interact with the non-integrated firms (cf. section 6).

Thirdly, Carlton (1979) assumes that because external suppliers/manufacturers induce transaction costs, vertical integration with market interaction would alleviate the gain from not buying or selling at an intermediary production stage. This would then be inconsistent with the idea that vertical integration is used to avoid transaction costs.

Fourthly, when integrated firm chooses not to interact with the intermediary market, they can create barrier to entry, because it can be difficult to new firm to enter the market without integrate all production stages. This is mostly the case when all the industry are vertically integrated and highly concentrated. However, market interaction is not totally incompatible with vertical integration. When new products are launched, it could be attractive to the upstream component of the vertical integrated firm to sell on the downstream market as it will increase its learning effect (i.e. the marginal cost decreases with quantity produced). This strategy is even more relevant when barriers to entry are high in the upstream market because it insures total control for the integrated firm. For an integrated firm, selling intermediate goods to the downstream firms can increase the scale of its upstream production, and thus reduce the upstream average costs (because of existence of a fixed cost). We illustrate the assumption that integrated firm can benefit from selling to competitors with the case of OLED TV constructors (cf. subsubsection 6.0.1).

3.1.3 Assumption 3: Ex-Ante or Spot Contract

We distinguish two main ways to define contracts among firms. On the one hand, contracts can be defined ex-ante and on the other hand, they can be defined at the current market price. The first one refers to forward contracts that "*obligate its owners to purchase one unit of a specified asset at a fixed price*" (Jarrow, 1981) while the second one refers to spot contracts which are settled to the price of the ongoing market situation.

All other things being equal, different outcomes could appear depending on which contracts type is chosen. For instance, if contracts are based on the current market price, the downstream market bears the risk that a shock on the upstream market increases the wholesale price (i.e. that production costs increase in the upstream market raise the wholesale price). Whereas if contracts are determined ex-ante, the downstream market should not be impacted by the shock and the upstream firm would have to bear the shock. However, if contracts are determined in advance, the upstream market will bear the risk of its production costs increase. This is why ex-ante contracts are usually more expensive than spot contracts, because they allow downstream firms to avoid price increase in the future. Note that in case of positive external shock, upstream market is benefiting when it uses forward contracts whereas downstream market is benefiting when it uses spot contracts.

3.2 Two-Stage Chain Supply Market

The two-stage chain supply model states a successive supply chain with two tiers that encompasses manufacturers (tier d) and inputs producers (tier u) with both n asymmetric firms. There are for now two type of producers: downstream and upstream firms where the downstream firms are located at tier d and the upstream firms are located at tier u. Suppose that market demand on the downstream level is linear and that a_d and b_d are parameters.

$$P_d = a_d - b_d Q_d \tag{1}$$

We assume a quantity competition mirrored by a Cournot competition and expect that each downstream firm (indexed by d,i) has infinite production capacity and then chooses its production quantity $q_{d,i}$. We consider that one part is required to produce one unit of the final product ("one-to-one conversion") and that $c_{d,j}$ is that downstream firm's variable unit of production cost. The price in tier u (wholesale price) is P_u while the price in tier d (the retail price) is P_d.

The subgame-perfect equilibrium is obtained by backward induction. Each downstream firm chooses a quantity which maximises its profits.

$$\begin{aligned} \pi_{d,i} &= (P_d - c_{d,i} - P_u) q_{d,i} \\ &= (a_d - b_d Q_{d,-i} - b_d q_{d,i} - c_{d,i} - P_u) q_{d,i} \end{aligned} \tag{2}$$

Where $Q_{d,-i} = Q_d - q_{d,i}$ represents the total production manufactured by the other firms in tier d. This yields the first-order condition:

$$\frac{\partial \pi_{d,i}}{\partial q_{d,i}} = 0 = a_d - b_d Q_{d,-i} - u b_d q_{d,i} - c_{d,i} - P_u$$

$$q_{d,i} = [a_d - n_d c_{d,i} + C_{d,-i} - P_u]/(n_d + 1) b_d$$

Where $C_d \equiv \sum_{n=i} c_{d,i}$ and $C_{d,-i} \equiv \sum_{j \neq i} c_{d,j}$. The individual downstream production would depend on the number of downstream competitors as well as the competitors production costs. We can add up all the individual downstream production to obtain the total production manufactured by tier d.

$$Q_d = \sum q_d = \frac{1}{n_d + 1} \frac{n_d a_d - C_d - n_d P_u}{b_d} \tag{3}$$

Substituting into the reverse demand function (1), we have

$$P_d = \frac{a_d + C_d + n_d P_u}{(n_d + 1)} \tag{4}$$

Such that the retail price (P_d) gets closer to the variable downstream production costs when the number of downstream firms increases. Note that the wholesale price (P_u) depends on the number of upstream firms in such a way that downstream price is also affected by the upstream competition. Now consider the second level of the supply chain (tier u). The number of parts demanded by final assemblers at a price P_u is equal to the quantity Q_d of the final product ($Q_u = Q_d$). This assumption comes from the "one-to-one conversion" where one part is required to produce one unit of the final product.

$$Q_d = \frac{1}{n_d + 1} \frac{n_d a_d - C_d - n_d P_u}{b_d}$$

$$P_u = a_d - \frac{C_d}{n_d} - \frac{b_d(n_d + 1)}{n_d} Q_d = a_u - b_u Q_u \tag{5}$$

Where $Q_d = Q_u$; $a_u = a_d - \frac{C_d}{n_d}$; and $b_u = b_d[\frac{n_d+1}{n_d}]$. We assume the same demand linearity as in the previous tier such that

$$Q_u = \sum q_u = \frac{1}{n_u + 1} \frac{n_u a_u - C_u}{b_u} \tag{6}$$

$$P_u = a_u - \frac{1}{(n_u + 1)}(n_u a_u - C_u) = \frac{a_u + C_u}{(n_u + 1)} \tag{7}$$

The upstream price equation confirms the assumption that the number of upstream firms negatively impact the wholesale price (P_u). Downstream profit would then be impacted by the number of downstream firms and the number of upstream firms. We are now substituting back (3) for a_u, b_u and P_u to get the downstream quantity with respect to the upstream price.

$$Q_d = \frac{n_d n_u a_d - n_u C_d - n_d C_u}{b_d(n_d + 1)(n_u + 1)} \tag{8}$$

As $P_d = a_d - b_d Q_d$, P_d equals

$$P_d = a_d - \frac{n_d n_u a_d - n_u C_d - n_d C_u}{(n_d + 1)(n_u + 1)} \tag{9}$$

Because we assume that downstream and upstream quantity produced are equal (i.e. $Q_d = Q_u$), we obtain the same upstream quantity than in (8)

$$Q_u = \frac{n_d n_u a_d - n_u C_d - n_d C_u}{b_d(n_d + 1)(n_u + 1)} \tag{10}$$

Considering the downstream and upstream quantities produced as well as the wholesale and retail price, we can solve the downstream and upstream profit. As mentioned before, downstream profit is

$$\pi_{d,i} = (P_d - c_{d,i} - P_u)q_{d,i}$$

$$\pi_{d,i} = \frac{1}{b_d}\left[\frac{n_u a_d - (n_d + 1)(n_u + 1)c_{d,i} + (n_u + 1)C_d + n_d^{-1}C_d - C_u}{(n_d + 1)(n_u + 1)}\right]^2 \tag{11}$$

Whereas upstream profit is

$$\pi_{u,i} = (P_u - c_{u,i})q_{u,i}$$

$$\pi_{u,i} = \frac{n_d}{b_d(n_d + 1)}\left[\frac{a_d - n_d^{-1}C_d - n_u c_{u,i} + C_{u,-i}}{(n_u + 1)}\right]^2 \tag{12}$$

We can forthwith point out the determinants of downstream and upstream profit. In a non integrated market, the downstream profit is function of competition on both the downstream market and the upstream market. However, increase in upstream competition induces a positive effect on the downstream profit as marginal production costs get closer to the upstream price (i.e. upstream market power is decreasing) while increase in downstream competition worses it. Downstream profit is also negatively impacted when upstream production costs increase but is positively impacted if downstream competitors suffer from higher production costs. The upstream profit is determined by the competitiveness in the upstream tier and the marginal production costs on both level.

3.3 Vertical Integration Model

The model with vertical integration states the same successive supply chain as before (e.i. n asymmetric firms on two tiers that compete with quantity) but there are now three types of producers: vertically integrated, downstream and upstream firms. We assume that n' firms at each tier decide to vertically merge to produce in-house. Still, we assume that market demand on the downstream level is linear and that a_d and b_d are parameters.

$$P_d = a_d - b_d Q_d \tag{13}$$

We consider that one part is required to produce one unit of the final product ("one-to-one conversion") and that $c_{d,j}$ is that downstream firm's variable unit of production cost while $c_{d,I,i}$ is the production costs of the downstream component of an integrated firm and $c_{u,I,i}$ is the production costs of the upstream component of an integrated firm. The subgame-perfect equilibrium is also obtained by backward induction where each downstream and integrated firm chooses a quantity which maximises its profit. We can aggregate separately the downstream and integrated quantity into the following equations.

$$\sum q_I = \frac{n'a_d + n'C_d - (n_d+1)[C_{d,I} + C_{u,I}] + n_d n' P_u}{(n_d + n' + 1)b_d}$$

$$\sum q_d = \frac{n_d a_d - (n'+1)C_d + n_d[C_{d,I} + C_{u,I}] - n_d(n'+1)P_u}{(n_d + n' + 1)b_d}$$

We can add up the aggregate production of the downstream firms with the aggregate production of the integrated firms to obtain the total production manufactured in the downstream tier.

$$Q_d = \sum q_d + \sum q_I = \frac{(n_d + n')a_d - C_d - C_{d,I} - C_{u,I} - n_d P_u}{(n_d + n' + 1)b_d} \tag{14}$$

Substituting into the revers demand function (13), we have

$$P_d = \frac{a_d + C_d + C_{d,I} + C_{u,I} + n_d P_u}{(n_d + n' + 1)} \tag{15}$$

Such that the retail price (P_d) is, as previously shown, a function of the number of downstream firms but also of the number of integrated firms as well as of the total production costs of the integrated firms (i.e. downstream and upstream). Now consider the second level of the supply chain (tier u). The number of parts demanded by final assemblers at a price P_u differs from the previous competition model as the quantity of the final product does not take into account the in-house production of the vertically integrated firms ($Q_u = Q_d - \sum q_I$).

$$
\begin{aligned}
Q_u &= \frac{n_d a_d - n_d P_u(n'+1) - C_d(n'+1) + n_d[C_{d,I} + C_{u,I}]}{(n_d + n' + 1)b_d} \\
P_u &= \frac{n_d a_d - C_d(n'+1) + n_d[C_{d,I} + C_{u,I}] - b_d(n_d + n' + 1)Q_u}{n_d(n'+1)} \\
&= a_u - b_u Q_u
\end{aligned}
\tag{16}
$$

Where $a_u = (n_d a_d - C_d(n'+1) + n_d[C_{d,I} + C_{u,I}])/n_d(n'+1)$ and $b_u = b_d(n_d + n' + 1)/n_d(n'+d)$. We assume that the upstream market demand is linear such that

$$
Q_u = \sum q_u = \frac{1}{b_u(n_u+1)}(n_u a_u - C_u) \tag{17}
$$

$$
P_u = a_u - \frac{1}{(n_u+1)}(n_u a_u - V_u) = \frac{a_u + C_u}{(n_u+1)} \tag{18}
$$

Substituting back the upstream price expression (18) for a_u, b_u, and P_u into (15).

$$
P_u = \frac{n_d a_d - (n'+1)C_d + n_d(n'+1)C_u + n_d[C_{d,I} + C_{u,I}]}{n_d(n'+1)(n_u+1)} \tag{19}
$$

$$
P_d = \frac{[(n'+1)(n_u+1) + n_d](a_d + C_{d,I} + C_{u,I}) + (n'+1)(n_u C_d + n_d C_u)}{(n_d + n' + 1)(n'+1)(n_u+1)} \tag{20}
$$

Considering the downstream quantities produced by the integrated firms as well as the wholesale and retail price, we can solve the profit for an integrated firm

$$
\pi_{I,i} = \frac{1}{b_d}\left[\frac{[(n'+1)(n_u+1) + n_d](a_d + C_{d,I} + C_{u,I}) + (n'+1)(n_u C_d + n_d C_u)}{(n_d + n' + 1)(n'+1)(n_u+1)} - c_{d,I,i} - c_{u,I,i}\right]^2 \tag{21}
$$

The profit of an integrated firm is function of the number of other integrated firms in the market as well as the number of downstream firms (it mirrors the downstream competition) and of the number of upstream firms that allows non integrated downstream firms to buy their input at a lower price. Next to that, the integrated firm's profit depends on its production costs and on the ones of its competitors.

4 Vertical Oligopoly Market

Many industries are organised according to an oligopolistic point of view (i.e. where imperfect competition prevails) but still the structure of the supply chains might vary. One could wonder whether the incentive to vertically integrated increases or decreases when the number of competing firms on either the downstream tier or either the upstream tier changes (Hypothesis 1). It would then illustrate the effect of market size. We compare the same two models developed before (i.e. Two-Stage Chain Supply Market and Vertical Integration Model), except that we fix the number of competing firms on one tier and increase it for the other tier. Because we make the assumption that vertically integrated firms only consume the in-house production, we need to add an extra firm in the upstream or in the downstream market (Assumption 2). Otherwise, we wouldn't have any market interaction. Moreover, we always look at the point of view of the firm located in the more concentrated tier. For instance, we will look at the incentive of being integrated upwards if the upstream market is the more competitive market and inversely.

As stated before, the equilibrium profit for the integrated firms is:

$$\pi_I = \frac{1}{b_d}\left[\frac{[2(n_u+1)+n_d]a_d - (2n_dn_u + n_d + 2n_u + 2)[c_{d,I} + c_{u,I}] + 2(n_uC_d + n_dC_u)}{2(n_d+2)(n_u+1)}\right]^2$$

We observe that π_I decreases when n_d and/or n_u increase (i.e. when the market becomes less concentrated) and increases when C_d and/or C_u increase. Because we state a linear Cournot model with homogeneous products, the integrated firm is negatively affected by the increase in competition at each tier but positively affected by any rivals' production costs increase.

While the equilibrium profits, for the two-stage chain supply market, are respectively for the downstream and upstream firms:

$$\pi_{d,i} = \frac{1}{b_d}\left[\frac{n_ua_d - (n_u+1)(n_d+1)c_{d,i} + (n_u+1)C_d + n_d^{-1}C_d - C_u}{(n_d+1)(n_u+1)}\right]^2$$

$$\pi_{u,i} = \frac{n_d}{b_d(n_d+1)}\left[\frac{a_d - n_d^{-1}C_d - n_uc_{u,i} + C_{u,-i}}{(n_u+1)}\right]^2$$

We observe that $\pi_{d,i}$ and $\pi_{u,i}$, respectively, increase when n_u and/or n_d increase and both decrease with competition on their tier. Downstream profit is decreasing with the upstream production costs but is increasing with the downstream rival production costs. Upstream profit is decreasing with the downstream production costs but is increasing with the upstream rival production costs.

It must be true that whether a firm chooses to be integrated depends on the expected payoff to do so. Such that we consider that the integrated profit must be superior or equal to the sum of the profit of a downstream firm and an upstream firm. Otherwise, they would stay in the competitive market.

$$\pi_I \geq \pi_{d,i} + \pi_{u,i}$$

This is also true that the double-marginalisation still applies in a vertical oligopolistic market (i.e. "*total output is thus lower than in an industry in which the input is supplied competitively at marginal cost*" (Belleflamme, 2014)). The decision of whether or not be to integrated depends then on the trade-off between escaping from the double marginalisation problem and the gain from specialising in the production stage (Dufeu, 2004). When the market becomes less concentrated (at each tier), the benefit from avoiding double marginalisation is less than the benefits of competition (Corbett and Karmarkar, 2001). "*Vertical integration may also have effects on the intensity of competition upstream and or downstream and associated price-cost margins and profits*" (Joskow, 2006).

4.1 Case 1: Integration with n Upstream firms

Figure 4 illustrates a highly concentrated downstream market with a competitive market on the upstream market. It depicts a market where a large number of suppliers provides inputs to a small amount of manufacturers. It generally represents the case of raw material industries where downstream market requires a high minimum scale of production. Firstly, we should expect an expansion of the bargaining power in the downstream market as the number of upstream firms increases (i.e. the influence of the upstream firms decreases as they face more competition). At the end, the intermediary good's price should then decrease to its marginal production costs.

Because the intermediary good's price tends to reach the marginal production costs ($P_u = c_{u,i}$) with competition, the downstream firm profit should equal the profit of the integrated firm when n_u tends to infinity. The intuition is that the upstream firms' markup decreases so that they can not distort the price anymore (Tirole, 1988). When n_u reaches infinity, profit on the upstream market is zero. With no loss of generality, in presence of imperfect competition in the upstream market, the integrated firm will always be better off than the sum of the profit of the downstream firm and an

upstream firm. Moreover, with vertical integration, the downstream component of the integrated firm should be better off because it reduces upstream competition (i.e. others downstream firms must buy their inputs at a higher price than before because the upstream market is more concentrate). Note that in this setup, the effect of the downstream rival costs on the integrated firm profit is stronger than the effect of the upstream rival costs as it is positively linked with the number of competitive firms in the upstream market and because the number of non integrated downstream firms is fixed to one.

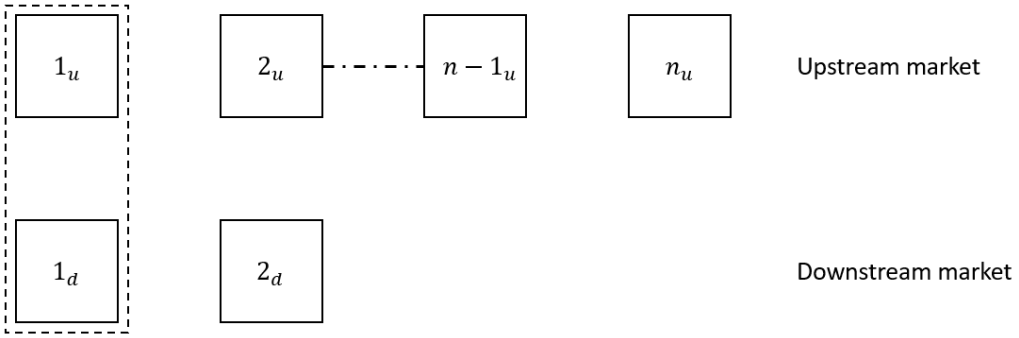

Figure 4: Integration with n upstream firms.

However, adding external shocks — mirrored by a production costs increase (cf. Assumption 1) — to the model can change its interpretation. At first, we can easily state that negative shocks on competitors will always have a positive impact on the profit of the firm (either for an integrated firm or a non-integrated one) and should not then change the outcome of the model. Integration will consistently give the best outcome under imperfect upstream competition because it benefits from cheaper input price.

A more interesting point would be to analyse the case whether a shock only happens to the integrated firm either on tier d or either on tier u. Firstly, as the downstream market is concentrated, a cost increase at tier d still gives incentive to vertically integrated if the downstream shock is low enough . However, if the shock is higher than the gain provided by avoiding the double marginalisation problem, the incentive of being vertically integrated disappears. Note that being vertically integrated allows to compensate a loss in the downstream market by recouping the margin in the upstream market. However, as the number of upstream firms increases, the double marginalisation problem faced by the other downstream firm disappears (i.e. it buys its input cheaper) and the potential margin of the upstream component of the integrated firm decreases.

Secondly, a costs increase at tier u gives another result. However, the result depends on whether ex-ante or spot contracts are chosen by firms (Assumption 3). If contracts are determined at a cur-

rent market price, the increase in the number of competitive firms in the upstream market shifts the incentive to be vertically integrated. It can be explained by the fact that at first glance the integrated firm benefits from producing its intermediate input at its marginal costs even when it suffers from additional costs but as the number of upstream firms increases, the intermediary good's price becomes cheaper than producing in-house and the downstream firm can easily buy from another more competitive upstream firm. Note that when markets are concentrated both downstream and upstream, vertical integration provides the best outcome, except when the upstream shock is higher than the gain from avoiding double marginalisation problem. According to Carlton (1979), "*firms are less likely to integrate when they form a small part of total demand for the input since they would lose the risk pooling economics of large markets as they integrate*". However, vertical integration could offset the variability in input demand which induces higher prices. Mahoney (1989) states that under costs or price uncertainties, "*a downstream firm has the incentive to purchase one or more upstream firms because this improves its pricing forecast and thus its ability to purchase the appropriate level of capital*". Note that if contracts are determined ex-ante, the downstream firm should not integrate except if the price premium is higher than the expected shocks minus the gain from integration.

4.1.1 Belgian Sugar Industry

Upstream market size effect can be depicted for most agricultural industries. This part will contain a brief description of the Belgian sugar industry and will explain the market power effect of the refineries (i.e. the downstream market) that allows them to buy beets from the upstream market at a break-even price. At first glance, there are unequal relations between upstream and downstream market. These relations were tightened up due to quota restriction in 2006 that induced a downstream concentration with several factory closures. For now, Belgian sugar industry is composed by 3 sugars factories (i.e. Fontenoy, Tienen and Longchamps/Wanze) owned by 2 sugar industrials (i.e. Iscal Sugar (IS) and Raffinerie Tirlemontoise (RT)) with 7.413 beet growers that supply these two industrials, respectively 2.756 for Iscal Sugar and 4.657 for Raffinerie Tirlemontoise (CBB, 2017). Nevertheless, there is a potential new player that can enter the Belgian market and lose these unequal relations of the sugar industry on beet growers. It would take the form of a vertically integrated firm wherein its suppliers would form a cooperative that controls its downstream manufacturer. Increase in downstream competition changes the bargaining power of upstream producers that were suffering from the excessive industrial's margin. One specific aspect to the relation between grower and manufacturer relates to significant transportation costs so that growers need to sell their beet to a nearby market. One other aspect is that beet price is determined ex-ante based on forward previsions (before the sowing period). This price depends on the industrial and diverge among them. These two aspects reflect how downstream refineries can benefit from higher bargaining power over the upstream growers.

4.2 Case 2: Integration with n Downstream firms

Figure 5 illustrates a highly concentrated upstream market with a competitive downstream market. This depicts a market where a small number of suppliers supplies a large number of retailers. It usually represents an upstream market with high fixed costs that requires to produce at a large scale or inputs scarcity. The bargaining power is now located in the upstream market. Following the same interpretation as in the previous model, when the number of downstream firms increases, the retail price decreases till it approaches its marginal downstream production costs increased by the upstream markup ($P_d = c_{d,i} + P_u$). In this case, integration does not always give the best payoff. At some point (i.e. when the number of downstream firms is high enough), the sum of the profit of the upstream firm and a downstream firm will become larger than the profit of the integrated firm. It can be explained by the fact that as the number of downstream firms increases, the upstream firms bargaining power increases as well. This phenomena reflects the increase in input demand that allows upstream firms to increase their margins. Even if increase in downstream competition also harms the downstream profits, the first effect prevails as compared to the gain from integration.

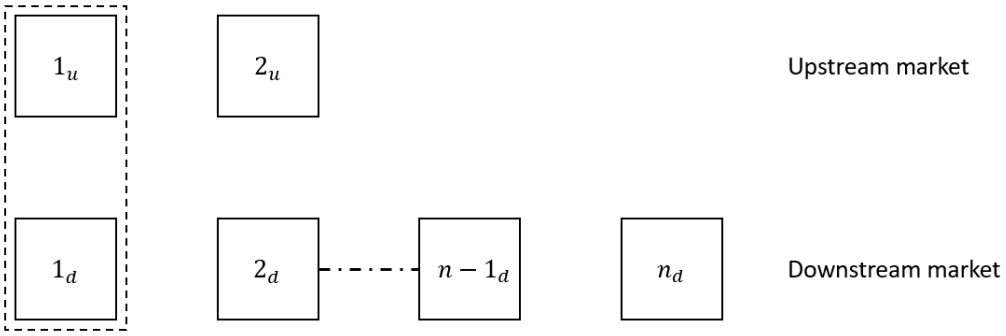

Figure 5: Integration with n downstream firms.

Barrera-Rey (1995) explains how imperfect competition in the upstream market can induce forward integration in a competitive downstream market and provides thus another result. Yet he assumes that when fixed proportion technology is not in stake (i.e. that final demand for downstream output requires different upstream output according to each technological level). According to him, "*in the case of variable-input technology the competitive segment is substituting away from the monopolist's output. In other words, the competitive industry uses too little of the monopolist's output. By integrating forward, the monopolist can convert that efficiency loss into its own profit and therefore expand input use to the optimal level*" (Barrera-Rey, 1995). However, in case of fixed proportion (i.e. one-to-one conversion) — as stated in this model —, the number of parts demanded by final assemblers is equal to the quantity of the final product such that there is no efficiency gain with forward integration when the upstream market is competitive.

Adding external shocks to the model slightly modifies the previous result. Firstly, external shocks in the upstream market do not change the insight of the model but modify the point where the integrated model gives the best payoff (i.e. the downstream market needs to be more concentrated than before to make integration profitable). However, when the other upstream competitor faces shocks, integration tends to be more rewarding than market competition. Yet, the opposite result appears when the upstream firm faces a shock and its upstream competitor doesn't. Because the upstream market is concentrated, the integrated firm benefits from the competitor production costs increase. Still, at some point, the increase in input demand will favour the non-integrated upstream firm because it benefits from more bargaining power than the integrated firm.

Secondly, the integrated firm benefits from costs increase in the downstream market as a whole and therefore also among parts of its competitors. But the propensity to integrate decreases when the firm is the only one to face external shocks. While the integrated firm is stuck with its downstream external shock because it is integrated with that specific firm, an upstream competitive firm can change its contractor (while it uses spot contract). Yet note that if the downstream shock is small enough, the upstream markup of the integrated firm can compensate the loss in its downstream part.

4.2.1 Flavour and Fragrance Industry

Downstream market size effect can be depicted for the flavour and fragrance industry. "*The industry is an oligopoly dominated primarily by Givaudan, Firmenich, IFF and Sumrise*" (Hahm, 2015). These big four account in 2017 for 56.5% of the world market share (Leffingwell & Associates, 2018). Flavours are mostly used for bakery, beverages while fragrances are used for cosmetics, soap, etc. Nonetheless, they are used in numerous applications and by large number of firms. Note that flavour is typically referring to a taste while fragrance is referring to a smell. In the flavour and fragrance industry, "*manufacturers have integrated their production and distribution channels for better market approachability. Most of these companies are vertically integrated and produce products that cater to various applications*" (Grand View Research, 2017). For instance, "*the larger companies (IFF and Givaudan) within the fragrance industry are vertically integrated back into fragrance ingredients or aroma chemicals*" (Tapuriah, 2003). However, if big players are usually integrated, smaller ones do not benefit from internal distribution networks and thus sell in the market. This industry mirrors then a concentrated upstream market with a large downstream market wherein big flavour and fragrance producers have integrated the downstream market (i.e. the distribution channels). Flavour and fragrance producers also integrated backwards to secure their inputs supply and benefit from low input price (Tapuriah, 2003).

5 Full Integrated Market

This section tries to understand how could evolve the incentive to integrate when all the industry is moving towards integration (Hypothesis 2). The model states a finite number n of symmetric upstream and downstream firms wherein we sequentially transform a downstream and an upstream firm into an integrated one (till the number of integrated firms (n') equals the number of firms in each tier (n)). It points out the profit of an integrated firm (π_I) when other firms start to integrate as well as its effect on non integrated firms ($\pi_u + \pi_d$) (cf. Figure 6 and 7). We also represent the profit obtained with our model without integration (π_c).

5.1 Case 3: Waves of Integration

When successive waves of integration appear in a market, there are multitude of concepts that come out. Firstly, when all the industry becomes integrated, it plays as a barrier to entry because any new incumbents should enter both stages to be able to produce. Note that this would only occurs if vertical integrated firms do not interact with external suppliers/manufacturers (Assumption 2). Secondly, consumers should be better off when all the industry is vertically integrated because firms avoid the double marginalisation problem (i.e. total production is increased and retail price is lower). Even if the market is composed by a large number of firms, there is always some inefficiencies that can be resolved with integration. Thirdly, when the industry starts to integrate, the non integrated firms are worse off because, on the one hand, upstream and downstream price are decreasing with the number of integrate firms.

$$P_u = \frac{n_d a_d - (n'+1)C_d + n_d(n'+1)C_u + n_d[C_{d,I} + C_{u,I}]}{n_d(n'+1)(n_u+1)}$$

$$P_d = \frac{[(n'+1)(n_u+1) + n_d](a_d + C_{d,I} + C_{u,I}) + (n'+1)(n_u C_d + n_d C_u)}{(n_d + n' + 1)(n'+1)(n_u+1)}$$

And on the other hand, non integrated firms also produce less than integrated one because they suffer from double marginalisation problem (i.e. producing in-house is cheaper than using external suppliers/manufacturers). Note that the non integrated firms' profit declines with the number of integrated firms because both market price and quantity produced by non integrated firms are decreasing (cf. Figure 6 and 7). Though integration induces anticompetitive effects, at a certain threshold of integration, the upstream price starts to increase again because inputs producers available on the market are scarce. Non integrated upstream firms should then be better off while downstream firms should suffer from higher inputs price as compared to before.

From our model, we also point out several key features: firstly, the first integrated firm in the industry always enjoys a higher profit than if it was not integrated (because it escapes from the double marginalisation problem). Secondly, the incentive to successively integrate increases with production costs. From a profit point of view and assuming low average production costs and no gain from integration except avoiding double marginalisation problem, integration only provides the best payoff for the first integrated firms (as compared to a situation without integration). Nonetheless, if average production costs are high, one should expect higher gain from integration (as compared to a situation without integration). Whether a firm benefits from cheaper production costs should negatively influence its gain from integration (i.e. if production costs are low, market is more remunerative than integration till a certain amount of firm integrates). Higher production costs favour then integration. Note that when one firm starts to integrate, others competing firms are worse off because the retail price is then lower. Vertical integration induces here a negative effect on non integrated firms. Thirdly, integration becomes less attractive when consumers' demand is high. When demand is high, firms can already extract huge profits even with the double marginalisation problem. However, when demand is low, only the most competitive firms sell on the market.

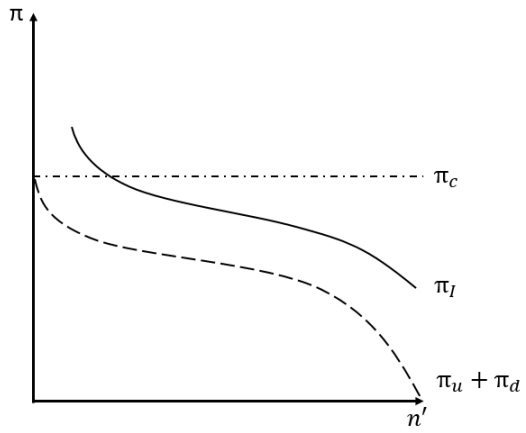

Figure 6: Integration trade-off with low average production costs.

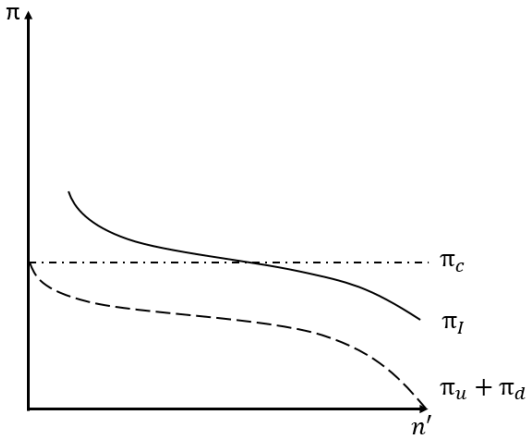

Figure 7: Integration trade-off with high average production costs.

Adding external shock to the model does not diverge from the main results. As stated, the incentive to integrate increases with production costs such that if external shocks appear — at one or both tier — one should expect an increase in integration. One should also point out that if shocks happen on one production stage, integrated firms can recoup part of their loss with the gain from integration. Still, one should observe that if shocks do not appear for all the industry, only the most competitive firms should integrate if they are facing consequent shocks. One should expect the firms to exit the market if their production costs are too high.

5.1.1 Oil Industry

The successive waves of integration concept can be illustrated with the oil industry. The oil industry is historically a moving industry wherein firms either integrate or disintegrate production stages according to the market structure (Stuckey and White, 1993). The industry is generally composed by a four production stages (i.e. "*oil and gas exploration, production and stabilisation of oil and gas, initial crude oil processing and oil refining*" (Devold, 2013)) and is highly influenced by market crude oil price. Note that the oil and gas exploration production stage is generally gather with the second stage (i.e. production and stabilisation of oil and gas). "*Crude oil production costs also vary widely across producers according to both the physical extraction costs and the opportunity cost due to the fixed reserve size*" (Gaudet et al., 1996). Gaudet et al. (1996) also determine that the more competitive upstream firms generally have larger downstream production costs because they specialise in their upstream productions instead of their refining part.

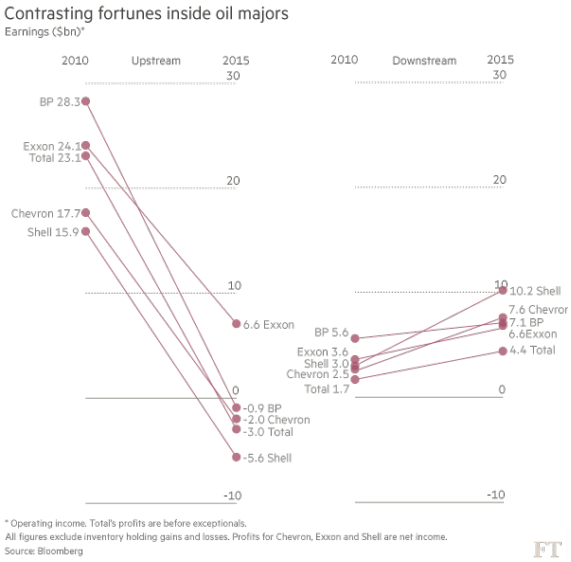

Figure 8: Oil Majors' income structure.
Source: Financial Times.

However and as mentioned before, integrated companies benefit from owning both upstream and downstream businesses because it creates a hedge against a loss in one part of the production stages (cf. Figure 8). For example, "*in 2014, Royal Dutch Shell generated $16.5bn in profit from its upstream operations and $6.3bn downstream. The following year, the balance flipped: upstream earnings slumped to just $1.8bn, while downstream profits remained roughly flat, adjusting for one-off items*" (Stacey and Crooks, 2016). It seems that the specificity of the oil industry is its cyclical market wherein downstream or upstream tiers gain or loss from changes in crude oil price. According to McKinsey (2015), "*the current oil price decline has the potential to trigger a wave of M&A activity*".

6 Discussion on integration with external suppliers/manufacturers

We assume here that the integrated firms can buy from the upstream competitors and/or sell to the downstream competitors. It alleviates the assumption 2 that vertical integration forces integrated firms to produce in-house intermediary good even in case of external shocks. We illustrate this issue by representing a model (Figure 9) that depicts a market with one integrated firm (its upstream part (1_u) and its downstream part (1_d)), three upstream firms (2_u, 3_u and 4_u) and three downstream firms (2_d, 3_d and 4_d). The black arrows represent the interactions either within the integrated firm or between the non-integrated firms while the dotted arrows represent the possible market interactions of the integrated firm with external suppliers/manufacturers.

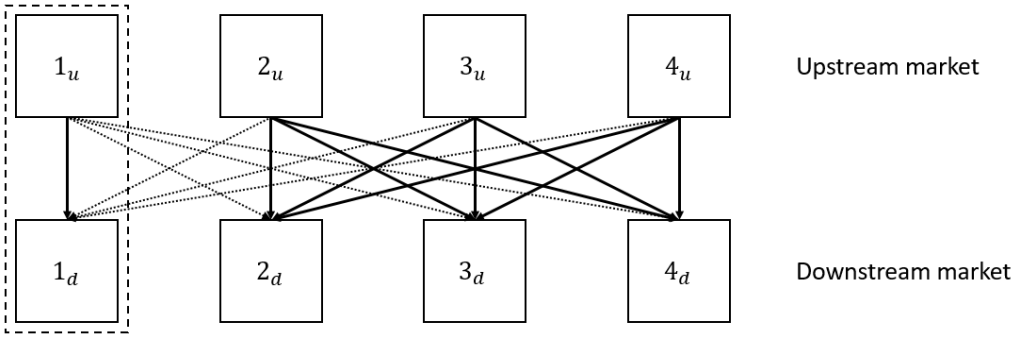

Figure 9: Integration with market interaction

Usually, an integrated firm faces the trade off between using its in-house production or taking part in the intermediate market, while the non-integrated firms use external suppliers/manufacturers to buy or sell inputs. For most cases, an upstream part of the integrated firm (1_u) that sells its intermediate goods in the upstream market will introduce more competition in the upstream market because it lowers the intermediate goods price. It will also introduce more competition in the downstream market as new additional final goods will be produced (if we assume that the integrated firm does not change its internal production). A downstream part of the integrated firm (1_d) can also buy from other suppliers to benefit from additional inputs to increase its final downstream production. Yet, it will decrease the upstream price as well as the downstream price. As a reminder, the upstream price depends on the quantity sold in the upstream market and does not take into account the quantity produced by the integrated firm except when it also sells in the market. While the downstream price relies upon the quantity produced by all downstream firms (even the integrated one). The vertical integrated firms' interactions with external suppliers or manufacturers induce then lower wholesale price and/or lower retail price.

However, at some point, it might be beneficial for an integrated firm to interact with external suppliers or manufacturers. It is mainly the case with new products implementation because fixed costs are high or when the production costs increases (for instance with external shocks). Firstly, in the case of new industry, selling to other competitors can be useful to increase total production and then decrease average cost and marginal cost (due to economy of scale and learning effect). Secondly, "*according to Salinger (1988), it is especially in the presence of increasing average cost that the integrated firms can have sometimes interest to take part in the intermediate market*" (Dufeu, 2004). For example, shocks can worsen firm's production costs in such a way that it might be beneficial to cover a part or all of the production process with external suppliers/manufacturers. This is more likely to happen when market power is low (i.e. when production costs are close to the market price). The integrated firm will then benefit from cheaper inputs as compared to its in-house production that suffers from a production cost increase. One can also highlight scale diseconomies between the two production stages that can appear if, for instance, the upstream part of the integrated firm suffers from unexpected shocks that reduce its total inputs production. External suppliers should then secure this inputs' loss for still benefiting from the optimal scale economies.

We underline two situations wherein shocks influence market interactions: when the upstream part of the integrated firm suffers from an external shock or when the downstream part of the integrated firm endures an external shock. Firstly, it must be true that an integrated firm won't interact with external suppliers if the condition below holds.

$$C_{u,I} + s_{u,I} \leq P_u$$

If the shock ($s_{u,I}$) does not bring the marginal cost of the upstream part of the integrated firm ($C_{u,I}$) over the upstream market price (P_u), the integrated firm does not have any interest to interact with the market. However, if the shock leads the marginal cost to be higher than the upstream price, the downstream part of the integrated firm has interest for buying in the upstream market. Unless the integrated firm has enough market power in its downstream component to still benefits from positive profit as an all. This should be explained by the negative impact an integrated firm can play on price whether it decides to sell or buy from the upstream market. Introducing more competition in the upstream market can be more detrimental that suffering from higher input price. We can argue that one advantage of integration is to compensate upstream negative shock by downstream positive profit.

Secondly, an integrated firm won't interact with external manufacturers if the following condition holds.

$$C_{d,I} + C_{u,I} + s_{d,I} \leq P_d$$

If the marginal costs of the integrated firm ($C_{d,I} + C_{u,I}$) exceeds the downstream price (P_d), the upstream part should sell its inputs in the upstream market as the downstream part isn't competitive enough to sell on the downstream market. Still, as mentioned before, if the markup of the upstream firm is high enough, the integrated firm will benefit from not interacting with the upstream market.

That being said, the willingness to trade within the upstream and/or downstream market depends mainly on the market power of the integrated firm and the intensity of the shock. Market power determines the ability to overcome the shock. If the integrated firm can appropriate a large margin, the shock won't always be large enough and the integrate firm would still be able to buy or sell in the upstream market. Nonetheless, if the negative shocks hit both parts of the integrated firm and are large enough, it is more likely that neither of them sells or buys from the market. While a non-integrated firm (either upstream or downstream) would collapse if it faces a too high negative shock, an integrated firm can handle a negative shock on one of its parts. But on the one hand, keep producing in-house, if the shock does not exceed the total margin of the integrated firm or on the other hand, by buying or selling in the upstream market to compensate for the shock it faces.

6.0.1 Organic Light-Emitting Diode (OLED) Industry

We now introduce a specific case of market interaction with integrated firms. It refers to our first argument: "New production implementation could foster market interaction due to high fixed cost". This part contains a description of the OLED TV Industry and depicts the interaction of the only OLED TV panel supplier (LG display) that sells its production either to its vertically integrated part and to other TV constructors (such as Philips, Panasonic and Sony). OLED TV industry is considered as an infant industry as it penetrated the tv market in 2012. In fact, LG display is not the only OLED panel supplier but it is the only supplier able to produce sizeable panels. This is due to the fact that big OLED panels require improved technologies as compared to smart-phone panels. For now, "*the manufacturing cost of a 55-inch OLED UHD TV panel has narrowed to 2.5 times that of an LCD TV panel with the same specifications, compared to 4.3 times back in the first quarter of 2015*" (IHS Markit, 2017) (Figure 10). One could explain the market concentration by the huge investment, the high level of expertise required and the small market share of the OLED TV as compared to LCD.

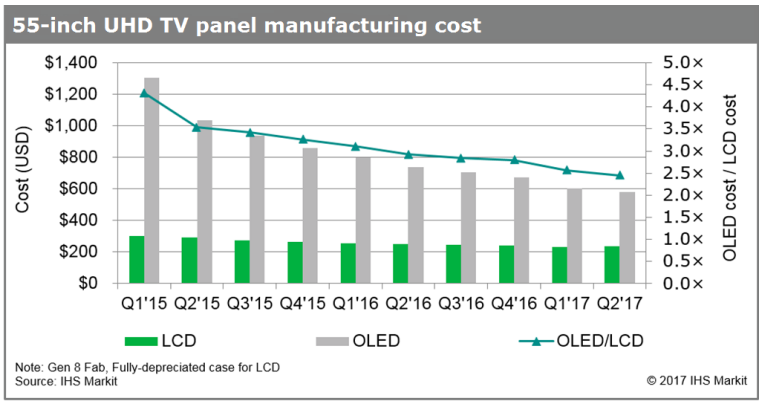

Figure 10: 55-inch Ultra HD TV (4k) panel manufacturing cost.
Source: IHS Markit.

The OLED industry reflects why an integrated firm can benefit from selling intermediary goods to its competitors on the upstream market. Here, accessing the upstream market would require huge investments from the other OLED TV manufacturers (i.e. investments mirror a huge barrier to entry). But through a learning effect, LG Display benefits from selling to its competitors because it decreases its marginal cost making OLED TV cheaper and more attractive to consumers. The OLED case would then confirm that integrated firms can — even when production costs are under the market price — use external manufacturers because they need to decrease their average production costs. However, one should suspect that this occurs due to huge fixed costs that play as barriers to entry. The gain generated by the upstream component of LG display is then larger than the costs generated by introducing more competition downstream. Because Lg display is the only OLED panel supplier, shocks either upstream or downstream should have no impact on its propensity to produce.

7 Conclusion

As we previously saw, the decision of integration relies on several determinants that are industry and firm specific. According to Barrera-Rey (1995) "*it seems that firms will decide to integrate for reasons related to the market structure, the characteristics of technology, the stage of maturity of the industry, and firm-specific factors*". Changes in the market structure should then adjust the incentives to integrate (Stuckey and White, 1993). However, whether to decide to vertically integrate or not should also depend on the trade-off between on the one hand the positive aspects of integration (i.e. avoid the double marginalisation problem, avoid transaction costs, secure a steady supply or facilitate a new technological shift) and on the other hand the downsides of integration (i.e. organisation costs' increase, possible scale diseconomies or sunk costs). Yet, the fact that one aspect prevails over the others is uncertain.

To point out this dilemma that firms face when they decide to integrate, we developed two models depicting a two-stage supply industry with n asymmetric firms and with either no integration and with it. Comparing these two models from an expected profit point of view allowed us to highlight the different outcomes appearing. These two models were presented for different situations that portray distinct industry pattern. Each of them providing different clues about why integration could be fostered or dampened. They emphasise the role of market size (Case 1 and 2), the role of being integrated when all competitors are integrating through all the stages of production (Case 3) and the impact of integration with external suppliers/manufacturers (Discussion in section 6). Furthermore, we tried to represent how external shocks — mirrored by production costs increase — can influence the willingness of integration (Assumption 1). At the same time, we noticed that production costs usually fluctuate according to external events or technological processes. This concept represented our main research purpose.

To do so, we firstly analysed — in section 4 — the effect of market size — either in the upstream and downstream market — on the incentive to vertically integrate (Hypothesis 1). At first glance, integration is regarded with respect to the trade-off between escaping from the double marginalisation problem and the gain from specialising at one stage (Dufeu, 2004). When the upstream market is competitive, the intermediary price tends to be located close to the marginal production costs such that the incentive to integrate forward is decreasing. Still, because markets usually reflect imperfect competition, integration can be remunerative. Moreover, we saw that if contracts are determined at a current market price, downstream firms are better off not to integrate — in presence of high upstream shocks and competitive upstream market — because they can buy at a cheaper price instead of pro-

ducing in-house. If contracts are determined ex-ante, the downstream firm should not integrate unless the price premium is higher than the expected shocks minus the gain from integration. When the downstream market is competitive, each additional downstream firm decreases the retail price till the downstream marginal production costs. However, as the number of downstream firms increases, the upstream firms bargaining power increases as well. Here, shocks in the downstream market discourage integration, except when the downstream market is highly concentrated. Increase in downstream competition reflects higher upstream bargaining power and than higher markup as compared to the integrated firm. We illustrated these two cases with the Belgian sugar industry and the flavor and fragrance industry, respectively for the upstream market size and the downstream market size.

The market size analysis also point out the following concept: being vertically integrated allows to compensate a loss in the downstream or upstream market by recouping the margin in the upstream or downstream market, respectively (Hypothesis 3). This is mostly favoured when one part of the supply chain is located in an oligopolistic market because the markup should be higher with oligopoly competition than with perfect competition. The upstream or downstream component of the integrated firm can then extract a higher surplus because it does not suffer from the double marginalisation problem.

Secondly, we developed — in section 5 — the incentive to integrate when part of or all the industry is moving towards integration (Hypothesis 2). We determined that when the industry is moving towards integration, the non integrated firms are worse off because the retail and wholesale price are decreasing as well as their quantity produced (because they are less competitive). In addition, it plays as a barrier to entry because new incumbents would require to enter both production stage as the number of non integrated firm is decreasing. According to the average industry production costs (i.e. low or high), the first firms benefit from integration while the non integrate ones suffer from it. We found out that when production costs are low, market is more remunerative than integration such that — when market is concentrate — external shocks that increase production costs for all the firms should encourage integration. However, if average production costs are high, one should expect more integration. To illustrate waves of integration, we developed the case of the oil industry that is an industry wherein firms historically either integrate or disintegrate according to crude oil price and its market structure. This industry also shows how integration allows to recoup loss in one stage by additional earning on other production stages.

Thirdly, we discussed — in section 6 — the effects of alleviating Assumption 3 (i.e. that integrated firms can interact with external suppliers/manufacturers in addition to their in-house production). The upstream and downstream component of the integrated firm can then, respectively, sell to the down-

stream market and buy to the upstream market. We determined that usually integrated firms do not interact with external suppliers/manufacturers as it introduces more competition that leads to lower retail price (Assumption 2). However, in case of new products implementation or when a component of the integrated firm suffers from external shocks, interaction with external suppliers/manufacturers can be beneficial. "*According to Salinger (1988), it is especially in the presence of increasing average cost that the integrated firms can have sometimes interest to take part in the intermediate market*" (Dufeu, 2004). Moreover, selling to competitors can — due to learning effect — reduce average cost. It is also true that to preserve scale economies between the two parts of the integrated firm, it might be beneficial to buy from external suppliers in case the upstream part would suffer from an external shock that reduces its input production. We exhibited this case with the OLED tv industry wherein a upstream OLED panel producer sell to its downstream component and other tv manufacturers.

Nonetheless, even when modelling different scenarios with and without uncertainty, it seems clear that decisions of integration largely depend on specific dimensions (e.g. asset specificity, industry structure,...) that are interconnected. This was shown by our different results that either foster or dampen decision to integrate. Providing a profit analysis should then serve as a reference point of view instead of a de facto point of view. Though, we assumed that uncertainty — mirrored by production costs increase — should play a key role on manager decision to integrate. Further researches should be made in the field of uncertainty and would link theory with empirical data. Moreover, we presume that providing more parameters to the model such as gains from integration with respect to the production costs would display other equilibria. In addition, one could also graphically and more precisely determine when would integration be profitable as compared to different situations and with respect to the probability of facing a shock and its intensity.

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