

Entry and Vertical Disintegration

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Abstract

Network industries, especially telecommunications, have been vertically disintegrating into firms separated by function, creating multiple, interdependent layers. We model this layering behavior, examining why it is happening, and how it impacts competitive outcomes. We argue that vertical disintegration reflects economies of scale in producing intermediate goods. As the market grows larger and/or transaction costs of coordinating services across networks become smaller, these intermediate scale economies become relatively more important and lead to vertical disintegration. Next, we consider entry into the market as a result of vertical disintegration. We show that even a small amount of entry into the less competitive segment of a vertically integrated industry can tip the entire industry toward disintegration.

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1 Introduction

In many network industries, most notably telecommunications, there has been a trend toward firms vertically separating by function, creating multiple, interdependent layers. For example, local broadband access networks consist of a conduit or poles layer, a cable coax or telephone copper wire layer, a powered channel layer linking customers to ISPs (where independence has been a contentious regulatory issue), an ISP-based Internet access portal layer, a content aggregators layer, and the content layer itself. We model this layering behavior, examining why it is happening, how it might impact competitive outcomes, and how it relates to the technology and the way it is implemented by operators.

We argue that vertical disintegration is motivated by economies of scale in intermediate goods production. As the market grows larger and/or transaction costs of coordinating services across networks become smaller, these intermediate scale economies become relatively more important and lead to vertical disintegration. We show this outcome in a model that formalizes some of the insights in George Stigler’s 1951 article “The Division of Labor is Limited by the Extent of the Market.”

We consider whether incumbents can manage this process of vertical disintegration and entry. We ask whether the incumbent gains or loses from entry. We also examine whether the incumbent can choose technologies that are socially inefficient (at least in the long run) to limit the scope of entry to complementary layers rather than the monopoly or oligopoly infrastructure. With sufficient technological lock-in, it may be possible for incumbents to limit the intermediate scale economies in ways that reduce the probability of entry into the infrastructure.

2 Stigler’s Model of Vertical Integration

Stigler published in 1951 a remarkable paper on Adam Smith’s famous theorem, “The division of labor is limited by the extent of the market.”¹ Stigler’s paper is regularly cited in the economics literature even though it does not seem to have had very much impact on vertical integration theory. Stigler’s paper follows by 23 years Young’s (1928) pathbreaking

¹A proposition Lowry (1879) traces back to the *Oeconomicus* by Xenophon. Kelly (1997) argues that the extent of the market itself is a function of factors such as the transportation and communication infrastructure that makes it possible to increase the extent of the market.

paper on the same subject.

It is useful to analyze Stigler's paper as consisting of three separate and largely independent stand-alone models. The first we will call the Division of Labor model, and it addresses Adam Smith's conjecture. Stigler's concern is based on the idea that the division of labor will be the source of firm-level economies of scale that would bring about a monopoly in each and every sector of the economy. As one does not observe monopolies throughout the economy, he asks whether Adam Smith's conjecture is wrong and writes his famous paper to establish that, in fact, this not the case.

The second model we call the Process model. He looks at a firm as an organized set of separate and distinct processes, thus introducing a classical dimension to the neoclassical production function. He equates the conventional neoclassical cost functions on a one-to-one basis with the firm's various individual activities. The approach is best conceived as an effort to bridge neoclassical analysis with team production (Becker and Murphy 1992). As shown by de Fontenay et al. (2004), it explains some flaws in treatments of economies of scale and scope (Panzar, 1989) as well as transaction costs (Williamson, 1985).

Stigler develops his Life Cycle Theory of vertical integration, what his paper is best known for, in the third stand-alone model. Describing firms in terms of a life cycle made up of three stages, he studies what may bring about vertical integration or disintegration in each of the transition periods between those phases. In the initial stage, vertical integration is inescapable because the firm has to carry out a number of activities that may not be available on the market. In the following stage, as the market matures, those activities are carried out by other firms that specialize in them. The outcome of the transition between those two stages is a gradual disintegration of the original firm. In the last transition phase, as the firm shrinks relative to the rest of the economy, vertically integration begins to reemerge. The Life Cycle model essentially reformulates the Process model in a quasi-dynamic form, using the dynamic structure to go around the static monopoly problem that was established in the first framework. This part of Stigler's paper has been reviewed extensively and continues to receive the most attention. Stigler's result is usually cited and set aside as it conflicts with the bulk of today's vertical integration literature (Joskow 2005). We show here that the conflict may not be as real as apparent. Conventional analyses of vertical integration tend to be short run (Williamson, 1985), and, on occasion, medium run (Perry 1989), while Stigler's framework is closer to Adam Smith's long-run perspective, one

that is more appropriate for policy formulation.

We argue that the individual models are most interesting as stand-alone studies, and this is what we focus on in this paper. We show that Stigler’s core issue – explaining why monopolies do not arise in Adam Smith’s framework – is not a problem in the first place. Adam Smith’s conjecture had already been established by Young (1928). Stigler’s concern reflects a confusion between economies of specialization associated with the division of labor and economies of scale that are central to modern theories of the firm. There are not necessarily links between the two, at least at the firm level, and for this reason monopoly need not arise.

3 Economies of Scale Versus Economies of Specialization

The concept of economies of scale (its foundations are discussed in de Fontenay et al. 2003 and de Fontenay et al. 2004) has always been problematic since it seems to lead inevitably to monopoly. Marshall (1920) stressed an aggregate concept of economies of scale with both internal and external economies rather than firm-level economies of scale. Later economists focused first on monopoly, then industry structure, and finally game theory to explain industries with market power.

In Stigler’s approach, the problem is pushed down from the firm level to the level of processes within the firm. He applies a conventional technology set (Mas-Colell et al. 1995) at a disaggregated level in the spirit of Adam Smith and his pin factory. The kind of processes Stigler lists to illustrate his approach includes processes such as “purchasing and storing materials, storing and selling outputs, extending credit to buyers” as well as the process of “transforming materials into semifinished products” (pg. 187). Effectively, Stigler’s firm is an entity that reflects an organized aggregation of distinct and *separable* activities that may correspond, say, to the units of its organization.

Stigler argues that the technological characteristics of those various processes are such that some may have substantial economies of scale. For instance, if we were considering a local telephone operator, most people think that the access network has substantial economies of scale while many of those same people are more at ease with the idea that those economies are not particularly significant at the retail level. Stigler, just like Williamson (1985), does not see separability as a significant problem, a conclusion that is supported by

some studies (e.g., Jacobides 2004) as well as by the high level of outsourcing one observes today (Feenstra 1998). Stigler observes that each of these cost functions will have their own technological characteristics, some, possibly, with significant scale economies, some, possibly, with diseconomies of scale. Thus, any economies of scale one may observe at the level of the firm are nothing more than *ex post* measures that need not describe in an *ex ante* manner the most efficient organization of the technology set.

This kind of approach was criticized in Young's (1928) key contribution:

“the principal economies which manifest themselves in increasing returns are economies of capitalistic or roundabout methods of production . . . these economies lie under our eyes, but we may miss them if we try to make a large-scale production . . . as contrasted with large production any more than an incident in the general process by which increasing returns are secured and if accordingly we look too much at the individual firms . . . the economies of roundabout methods depend upon the extent of the market - and that, of course, is what we discuss under the head of increasing returns.”

Young argues that it is improper to equate economies of specialization created by the division of labor with economies of scale at the intermediate good level. After a long hiatus, economists such as Yang (2001), Becker and Murphy (1992), Brown (1992), and Robertson and Alston (1992) are examining the difference between the two. Those analyses show how the division of labor generates, as noted by Young, a downward sloping aggregate output curve, a curve that might be adequate at times at the industry level. But that curve does not tell us anything about the efficient firm size. A lower point along the curve could just as well be associated with smaller units of production as with larger ones. Stigler's monopoly dilemma arose because he confused this *ex post* residual curve for the economies of scale of a neoclassical production function. Yang (2001) develops this more formally:

“the system of production . . . seems to exhibit economies of scale . . . But economies of specialization differ from economies of scale. First, economies of specialization are individual-specific and activity-specific . . . Second, the individual-specific time constraint and individual-specific system of multiple production functions are essential for defining the concept of economies of specialization.” (p. 46)

To incorporate these insights into a model, we adopt elements of Stigler, Young, and Yang (2001). From Stigler, we take the Process model, which could also be referred to as “Stiglerian specialization.” The key to that model is that if more labor (or another resource)

is allocated to an intermediate process, it produces a more-than-proportionate increase in output of the intermediate good.

From Young, we take the idea that these intermediate processes are *non-seperable*, so that intermediate scale economies do not automatically result in aggregate scale economies. Indeed, for a given division of labor, aggregate diseconomies of scale seem more likely. Thus, the transformation of labor into intermediate good x may be subject to scale economies, and likewise with intermediate good y , but the final good production function $f(x, y)$ is subject to diseconomies of scale. Following Young's logic, the only way to avoid these final good diseconomies of scale is to reconfigure the technology to include more processes. Thus, if an additional intermediate good z were created, then $f(x, y, z) > f(x, y)$ even when the initial labor input is the same. This is the case of "economies of roundabout production" or "Smithian specialization."

From Yang, we use the insight that these economies of scale and specialization are only determinants of how factors should be allocated, not vertical integration. The decision to vertically integrate is based on various organizational systems that we call the "commons." The commons includes property rights, residual claims, contracting, governance, and so forth. Models of these systems include Alchian and Demsetz (1972), Grossman and Hart (1986), and others. A complete analysis of the commons is beyond the scope of this paper. Here we use Coasian transactions costs as a convenient shorthand for the organization of the commons.² In fact, we interpret Williamson's body of work as an extended discussion of why this shorthand works well. We acknowledge that transactions costs do not always equate to property rights based models (Whinston 2001), but we believe they serve well for our purposes.

4 Model

In this section we present a model that addresses the previous discussion. Following on that discussion, firms in our model do have intermediate scale economies, but they do not have aggregate scale economies. Thus, no firm can expand to create a monopoly, but there are incentives for firms to engage in Stiglerian specialization and trade with one another. If there are limits on the number of firms that can enter (e.g. regulation or high fixed

²This is also Yang's approach.

costs that create integer constraints), then the firms will earn Ricardian rents (or quasi-rents depending on the source of the entry barrier). It is these Ricardian rents, rather than oligopoly rents, that create incentives for firms to try to manipulate the market.

We begin with a simple case of vertical integration, and then consider the more complex case of specialization.

4.1 Vertical Integration

Firms produce a final good q . We can think of this as a consumer good, such as residential telephone service. Production of the final good is subject to decreasing returns to scale because of marketing and/or quality problems associated with large scale. Each firm is a perfect competitor that takes the price of q , p_q , as given.

Firms need two intermediate goods, x and y , to produce output q according to the production function $q = f(x, y)$.

Assumption: Final good production is subject to *decreasing* returns to scale. $\alpha f(x, y) > f(\alpha x, \alpha y)$ for $\alpha > 1$.

Each firm has a quantity of critical resources L available to allocate between producing intermediate goods x and y . The number of firms thus fixes the total supply of L available in the industry.³ The firm allocates L_y resources to y production and $L - L_y$ resources to x production. Assume that the intermediate production functions are the same: $y = g(L_y)$ and $x = g(L - L_y)$.⁴

Assumption: Intermediate goods production is subject to *increasing* returns to scale. $\alpha g(l) < g(\alpha l)$ for $\alpha > 1$.

Since L is a finite resource, the intermediate scale economies create a tradeoff which is illustrated in Figure 1.

³Using the letter “L” for this variable suggests that the critical resources are specialized labor, but in fact specialized capital is probably more relevant in many industries.

⁴We believe this assumption does not affect the results in an interesting way, but it does economize on notation and complexity.

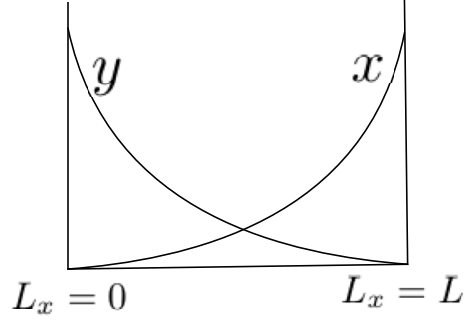


Figure 1: Intermediate Goods Production

The firm chooses L_y optimally according to the cost-minimizing first order condition

$$\frac{d}{dL_y} f(g(L - L_y), g(L_y)) = f_1 g_1(L - L_y) = f_2 g_1(L_y)$$

where number subscripts denote partial derivatives. The quantity of q produced is q_v^* , and let x_v^* and y_v^* denote the optimal production of the intermediate goods. Note that supply is perfectly inelastic because each firm uses up its entire endowment of L .

Let market inverse demand be $P(Q_d)$ where Q_d is the total quantity of the final good demanded. If there are N firms, then the market price is

$$p_q^* = P(Nq_v^*)$$

At this price, the profits of one of the vertically integrated firms are

$$\pi_v = p_q^* q_v^*$$

4.2 Stiglerian Specialization

Now we modify the above model to allow the firms to specialize à la Stigler in producing input y or x . Assuming all firms still produce the final good q , Stiglerian specialization requires them to trade inputs with each other in order to satisfy the requirements of the production function.

Following Yang (2001), we add a “melting iceberg” transaction cost for factors traded between firms. For example, if a firm purchases 10 units of y , it may find that only 9 units actually contribute to production. The other unit (or at least the cost of it) can be thought of as melting away, representing a transaction cost. We use the parameter $k \in [0, 1]$ to represent the degree of transaction cost. In the example we just gave, $k = 0.9$.

A higher value of k means lower transaction cost, since more of the input is actually used in production.

4.2.1 Firm-Level Optimization

Consider a y specialist. It uses all of its resources to produce y ($L_y = L$). It sells some of the y on the market (y_s) and uses the rest for production of q . It must buy the x factor in the intermediate goods market (x_d). Then its production function is

$$q_y = f(kx_d, g(L_y) - y_s)$$

and its profit function is

$$\pi_y(q_y, x_d, y_s) = p_q q_y + p_y y_s - p_x x_d$$

Assuming an interior solution, the the y -specialist solves:

$$kp_q f_1 - p_x = 0 \quad -p_q f_2 + p_y = 0$$

Denote the solutions to this system by x_d^* and y_s^* .

Other than the transaction cost k , these first order conditions are identical to those of a standard perfectly competitive firm. If, for example, p_y were to rise, the firm would cut back on internal use of y . But since the firm is a y specialist, it would still produce the same total quantity of y and sell more of it into the intermediate goods market.

For an x specialist the problem is reversed but otherwise identical due to the symmetry assumption. An x specialist's optimal purchases and sales are y_d^* and x_s^* . However, the presence of transaction costs introduces a wedge between the factor intensities of the two types of firms:⁵

Proposition: A y specialist produces q with a more y -intensive process than an x specialist.

Proof: Follows directly from the k term in the first order condition which adds to the cost of x_d from a y -specialist's point of view.

⁵An interesting extension would allow the quality of final good q to vary with the input mix. For example, x might represent cable television content and y might represent picture quality.

Finally, we can show that for any given intermediate good prices, every firm will choose Stiglerian specialization:

Proposition: All firms specialize in producing intermediate good x or y . No firm will produce a mixture of the two intermediate goods.

Proof: Consider a “mixed firm,” i.e. one that produces some x and some y internally but also participates in the intermediate good market. Without loss of generality, let the firm produce and sell y and produce and buy x .

The mixed firm allocates L_y resources to y production and $L - L_y$ resources to x production. Its profit function is

$$p_q f(g(L - L_y) + kx_d, g(L_y) - y_s) + p_y y_s - p_x x_d$$

Taking first order conditions, and assuming an interior solution, the mixed firm solves:

$$-f_1 g'(L - L_y) + f_2 g'(L_y) = 0 \quad kp_q f_1 - p_x = 0 \quad -p_q f_2 + p_y = 0$$

The last two first order conditions indicate that the mixed firm chooses the same *total* quantities of x and y for final good production as a y -specialist firm. Substituting the second and third conditions into the first gives

$$\frac{g'(L_y)}{g'(L - L_y)} = \frac{p_x}{kp_y}$$

But g is an increasing convex function, so this solution is not a maximum. ■

4.2.2 Market Equilibrium

Let the number of firms of each type be N_x and N_y . Then demand equals supply in the intermediate and final goods markets requires that:

$$N_x y_d^* = N_y y_s^* \quad N_y x_d^* = N_x x_s^* \quad Q_d = N_x q_x^* + N_y q_y^*$$

These can be solved simultaneously to give the equilibrium factor prices of x and y given the price of final output p_q . Now we can find the profits of the two types of firms.

More y firms decreases the price of y relative to x and therefore tends to decrease y firm profits. More firms of both types increases overall q supply, which can increase or decrease industry profits depending on the elasticity of demand.

5 Equilibrium Configurations

5.1 Comparison

Now the question that concerns us is whether a firm is better off in the vertical integration setting or the Stiglerian specialization setting. This depends on both the number of firms of each type (N_x and N_y) and the transaction costs involved in trading inputs between firms (k).

For now, let the number of firms be fixed and their specialties be predetermined. We will consider their selection process later.

Proposition: If $f(\cdot, \cdot)$ is homothetic, $\frac{N_x}{N_y}$ is close enough to the vertical integration $\frac{x_v^*}{y_v^*}$, and k is sufficiently large, then specialization with trade is efficient.

Proof: The total supply of x and y is determined by N_x and N_y under specialization. Each specialized firm chooses the same factor intensities when $k = 1$, and by homotheticity these factor intensities are optimal since they are the same as a vertically integrated firm would choose. Therefore, every firm is operating at an optimal factor intensity and with more of each factor, yet no more critical resources are being used. ■

If the conditions above are not met – e.g. if transaction costs are large or the number of firms of each types makes the factor mix is suboptimal under specialization – then the results could be reversed.

While this proposition is good for society, it may prove small comfort to the firms. Depending on the elasticities of demand and supply, the new lower-price, higher-quantity equilibrium may either increase or decrease producer surplus. Indeed the current move toward outsourcing seems to be accompanied by decreased producer surplus in some industries.

To see how this process plays out in an example, we adopt specific functional forms and compute the profits numerically. Specifically, suppose that the final good production function is Cobb-Douglas:

$$q = f(x, y) = x^{1/4}y^{1/4}$$

and that the intermediate production functions are

$$g(L_y) = L_y^2 \quad g(L - L_y) = (L - L_y)^2$$

Let demand be constant elasticity with $\epsilon = -2$:

$$P(Q) = 100Q^{-1/2}$$

Suppose $L = 2$ and for the vertically integrated case, let $N = 10$. For the specialization case, let $N_x = N_y = 5$, which will preserve the optimal half-and-half factor mix of the production function.

First, consider the effect of changes in k . Profits of the two types of firms under specialization are the same due to symmetry. The results are in Table 1:

k	π_v	$\pi_x = \pi_y$
.4	31.62	30.45
.5	31.62	31.31
.6	31.62	32.03
.7	31.62	32.66
.8	31.62	33.21
.9	31.62	33.70
1.0	31.62	34.14

Table 1 ($N_x = N_y = 5$)

Profits rise as k rises, indicating lower transactions costs. At about $k = 0.55$ it is more profitable to be specialized. This is due to the rather strong intermediate economies of scale embedded in $g(L) = L^2$.

Now we repeat this exercise, but with $N_y = 4$ and $N_x = 6$. This introduces the idea that the y firms are “incumbents” who may have some scarcity rents from their infrastructure.⁶ The y factor will command a higher price, and the x firms will be at a disadvantage. For the vertically integrated case, we report profits both for $N = 4$ and $N = 10$. The former is the case where under vertical integration, no y is available to the x firms and therefore they cannot produce. The latter is the case where all firms can produce y under vertical integration.

⁶Note the implication that the y infrastructure is a rival good, implying some sort of capacity constraint.

k	$\pi_v (N = 4)$	$\pi_v (N = 10)$	π_x	π_y
.4	50.00	31.62	28.41	33.19
.5	50.00	31.62	29.22	34.06
.6	50.00	31.62	29.89	34.84
.7	50.00	31.62	30.47	35.52
.8	50.00	31.62	30.98	36.12
.9	50.00	31.62	31.44	36.65
1.0	50.00	31.62	31.86	37.14

Table 2 ($N_x = 6, N_y = 4$)

The key result here is that the incentives to specialize are different for the different types of firms due to the suboptimal factor mix.

5.2 Specialization Equilibrium

What configuration of firms will emerge in equilibrium? This section is tentative, but will examine this question.

Suppose we consider the situation in Table 2 and interpret the y firms as 4 incumbents and the x firms as 6 potential entrants. Then the profits in Table 2 imply several results concerning the equilibrium configuration. (At this point these results are somewhat speculative since we have only this one parameterization, but we think it will not be difficult to formally prove results along the lines of what we describe here.)

Incumbency Advantage: The y firms' highest profits are when no entry occurs (the $N_x = 0, N_y = 4$ case). One can imagine that for other parameter values, however, that the y firms would prefer specialization with $N_x = 6, N_y = 4$.

Entry Incentives: The x firms generally prefer to enter with full integration (e.g. by building their own networks), at least provided that fixed costs are not too high. But the y firms do better with specialization. Thus, it would make sense for the y firms to try to induce specialization, for example by paying the x firms lump sums or even pricing below marginal cost.

Limited Number of Entrants: It appears from Table 2 that six vertically integrated entrants would join the market if they could. However, we know from Table 1 that

the firms generally do better under specialization with just five y firms. Thus, we would expect that if just one vertically integrated firm entered, then the equilibrium would tip to specialization just like in Table 1.

Mothballing: If there were fewer than 4 x firm entrants, the factor intensities would be suboptimal – there would be an x shortage. But this could be fixed if some of the y firms would “mothball” their network infrastructure and become x specialists. The extent of such mothballing would depend on risks of future entry, the ease with which the mothballed facilities could be restarted, and so forth.

6 Conclusion

The model presented here uses transactions costs to proxy for the environment that controls vertical integration decisions. It shows that when the number of firms is limited, different types of firms may have different incentives to move toward Stiglerian specialization.

We plan to extend the model in several ways. The most important is to examine the idea of an equilibrium configuration more closely. At first blush, it appears that there are multiple equilibria in the static model, some of which may be more efficient than others. We need to consider how such equilibria come about in a dynamic process and whether they are stable. Also, since specialization can sometimes reduce producer surplus, we want to examine when an industry can successfully resist it and when competitive pressures force specialization.

The next extension is to vary the factor intensity. As we suggested in the introduction, if the y firms are first movers and can lock in the technology, then they may be able to manipulate future specialization decisions in their favor by changing the factor intensity. In fact, we expect that different factor intensities will be most profitable depending on the elasticity or inelasticity of demand for the final good.

Finally, the model currently rests on a fixed endowment of critical resources (L) per firm. One would expect that firms would seek to change this endowment, but it would also seem reasonable that the endowment cannot be changed instantaneously. We will use an adjustment model similar to the one used in Gowrisankaran and Holmes (2004) in a paper on endogenous mergers in an industry. We expect that the pattern of specialization will profoundly influence investment in critical resources.

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