Entry and Vertical Disintegration

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Abstract

We formalize and extend George Stigler's famous article "The division of labor is limited by the extent of the market." We emphasize economies of scale in intermediate goods production as a determinant of firm boundaries and vertical control. We show that there are potential coordination failures which may prevent efficient vertical disintegration, and we discuss how these might be either overcome or used to the advantage of incumbent firms.

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1 Introduction

George 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, but it focuses on the cost functions of perfectly competitive firms whereas most recent vertical integration theory focuses on game theoretic models of vertical foreclosure.

Our goal is to clarify Stigler's reasoning and present a model of vertical integration and disintegration that preserves Stigler's emphasis on perfect competition and cost functions. In large part, we integrate the analysis of an older paper, Young's (1928) pathbreaking study of the same subject. We will obtain only some of Stigler's results from our model, and we will argue that the remaining results require additional elements beyond a group of identical, perfectly competitive firms.

Stigler's paper consists 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 asks whether 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. He concludes that there are always diseconomies of scale in some of the processes carried out by the firm, and these prevent monopolies from occurring.

The second model we call the Process model. Stigler looks at a firm as an organized set of separate and distinct processes, thus introducing a classical dimension to the neo-classical production function. He models the conventional neoclassical cost functions as the additively separable sum of 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

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[1]A 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.

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 firms. In the last transition phase, as the firm shrinks relative to the rest of the economy, vertical 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.

The rest of this paper is organized as follows. In section 2 we discuss Stigler's Division of Labor model and the questions it raises. Section 3 presents a formal model based on Stigler's Process model. In section 4 we turn to his Life Cycle model, and in section 6 concludes.

2   Economies of Scale Versus Economies of Specialization

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.

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.

3   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 costs that create integer constraints), then the firms will earn Ricardian rents (or quasi-rents depending on the source of the entry barrier).

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

3.1   Vertical Integration

Firms produce a final good q. We can think of this as a consumer good. 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

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[2]This is also Yang's approach.

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.
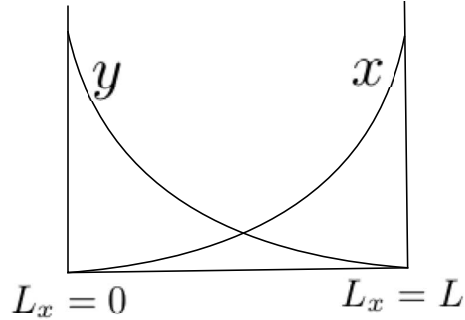

$$L_x = 0 \qquad\qquad L_x = L$$

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

$$p_q^* = P(N q_v^*)$$

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[3]Using 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.

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

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

$$\pi_v(N) = p_q^* q_v^*$$

3.2 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.

3.2.1 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

$$p_q q_y + p_y y_s - p_x x_d$$

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

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

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 1: 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.

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

Proposition 2: 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:

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

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. ∎

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[5]An 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.

3.2.2 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:

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

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.

4 Equilibrium Configurations

4.1 Specialization

Now the question that concerns us is whether a firm is better off in the vertical integration setting or the Stiglerian specialization setting. Let a **configuration** (N_v) or (N_x, N_y) give the number of firms of each type (vertically integrated, x specialist, and y specialist; by Proposition 2 hybrids will not occur).

Proposition 3: 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 type 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. In the remainder of this paper, we will assume that demand is elastic so that specialization is potentially profitable for the firms. For simplicity, we will also assume that the optimal factor mix is equal proportions of x and y, so that the optimal specialization configuration will have equal numbers of firms of each type.

4.2 Equilibrium Vertical Integration Configurations

Suppose that acquiring the critical resources L requires investment of a fixed cost F. A configuration is an ***equilibrium vertical integration configuration*** if an additional vertically integrated firm could not make a positive profit. Configuration (N_v) is an equilibrium vertical integration configuration if:

$$\pi_v(N_v) \geq F > \pi_v(N_v + 1)$$

The operating profits of the firms in configuration (N_v) would be determined by perfectly competitive equilibrium and would be represented by the horizontal line in Figure 2.
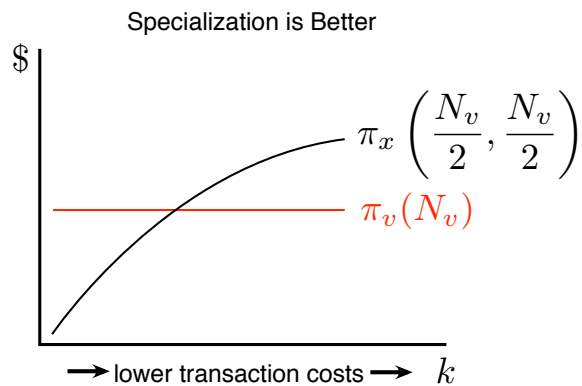

Figure 2: Operating Profits as a Function of Transaction Costs

Proposition 4: There exists a unique equilibrium vertical integration configuration.

Proof: Demand is downward-sloping and the quantity produced by any one firm is limited by L, thus revenue must decrease as the market quantity supplied rises. ∎

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4.3 Equilibrium Specialization Configurations

Now consider specialization. Configuration (N_x, N_y) is an ***equilibrium specialization configuration*** (ESC) if:

$$\pi_x(N_x, N_y) \geq F > \pi_x(N_x + 1, N_y)$$

$$\pi_y(N_x, N_y) \geq F > \pi_y(N_x, N_y + 1)$$

$$\pi_x(N_x, N_y) \geq F > \pi_x(N_x + 1, N_y + 1)$$

$$\pi_y(N_x, N_y) \geq F > \pi_y(N_x + 1, N_y + 1)$$

The first two conditions consider asymmetric configurations where there are more of one type of firm than the other. For example, with more x firms than y firms, there is an assymetry in the intermediate goods market: relative to the optimal factor mix, there is a surplus of x and a shortage of y. Thus, the y firms earn additional quasi-rents while the x firms earn less. Because profits are lower due to the suboptimal factor mix, it is possible that both of the first two conditions are met but that entry by one firm of each type would nonetheless increase profits. Thus, the third and fourth conditions are also required.

Definition: A specialization configuration is ***proportionate*** if the ratio of x to y firms is the same as the optimal marginal rate of transformation in a vertically integrated firm.

Consider the proportionate configuration $\left(\frac{1}{2}N_v^*, \frac{1}{2}N_v^*\right)$ in which there are the same total number of firms as under vertical integration, but they specialize. Assuming the production function meets the conditions in Proposition 3, the operating profit would be represented by the rising curve in Figure 2. However, we might not expect that $\left(\frac{1}{2}N_v^*, \frac{1}{2}N_v^*\right)$ is an equilibrium since operating profits are higher under specialization. We illustrate the situation in Figure 3 for the case where n additional firms of each type are viable at $k = 1$.

4.4 Static Industry Configuration Games

We have now defined equilibrium vertical integration configurations and equilibrium specialization configurations. It remains to analyze which type of equilibrium will actually emerge. Suppose that for a given k, the equilibrium vertical integration configuration is
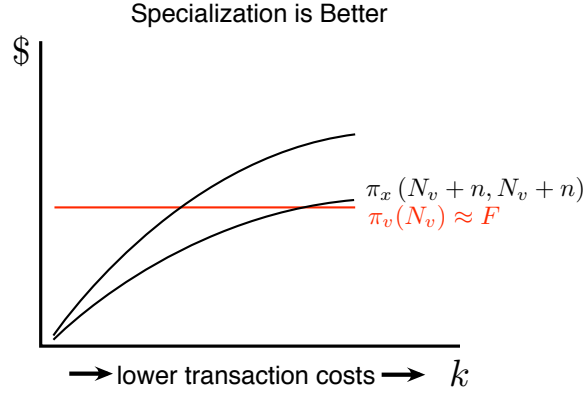
Specialization is Better

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$\pi_x\left(N_v + n, N_v + n\right)$
$\pi_v(N_v) \approx F$

→ lower transaction costs → k

Figure 3: ESC has n More Firms of Each Type

(N_v^*) and the equilibrium specialization configuration is (N_x^*, N_y^*). For example, for k given by the vertical dashed line in Figure 4, the relevant configurations are (4) and $(3, 2)$. (With total symmetry, $(2, 3)$ would also be an equilibrium, but we will ignore it here.)

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$\pi_y(3, 2)$
$\pi_x(2, 2) = \pi_y(2, 2)$
$\pi_v(4)$
$\pi_x(3, 2)$
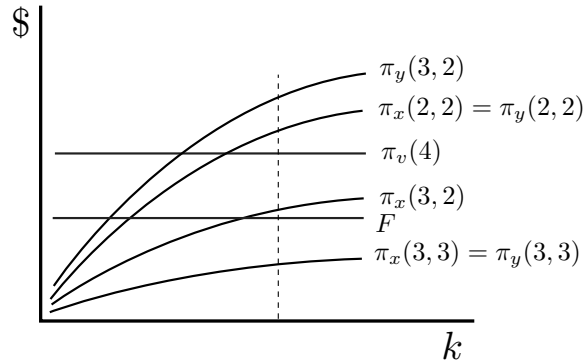F
$\pi_x(3, 3) = \pi_y(3, 3)$

k

Figure 4: Two Equilibrium Configurations

Either of these is a Nash equilibrium, in the sense that no firm can profitably deviate by a unilateral decision to enter or exit the market or to vertically integrate or specialize. Configuration $(3, 2)$ is socially efficient in that it involves more output for lower variable and fixed costs. By our assumption that final good demand is elastic, we also know that $(3, 2)$ brings in greater revenue to the industry as a whole. However, $(3, 2)$ is much more desirable to the 2 y specialists than to the 3 x specialists.

We can imagine many different mechanisms by which the actual configuration would be chosen. To begin analyzing these, let us take a simple, static game. Suppose that the industry has N_v vertically integrated firms due to past conditions. Suppose there is

an *unexpected* reduction in transaction costs that creates a new equilibrium specialization configuration (N_x, N_y). Given our assumptions, this configuration is proportionate, and if the optimal factor proportions are symmetric then the configuration is also symmetric.

If $N_x < N_v$ and $N_y < N_v$, then the incumbent firms cannot all specialize in the same intermediate good and still stay in the industry. Thus, a shift to the specialization configuration always involves a reallocation of L from x to y production *or* from y to x production in incumbent firms; and may involve *both* types of reallocation occurring at different firms. Thus, it is not possible to move to specialization unless some incumbent firms are willing to "mothball" or "abandon" their capabilities in one or the other intermediate good. 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. If incumbents are not willing to mothball, then the whole industry can be held away from the specialization equilibrium.

5   Conclusion

5.1   Stigler's Questions

We can now look back at our model to answer the questions Stigler posed in his paper. The first question was why the division of labor does not ultimately lead to monopoly. In our model, monopoly does not emerge in the final good market because there are decreasing returns to scale in assembling the intermediate goods. This is very similar to the answer that Stigler gave, in which he claimed that some processes used in producing final output would be subject to decreasing returns. One way of looking at our model is that we have included just such a process, namely the final combination of intermediate goods.

But this does not answer the question of monopoly in the intermediate goods market. Stigler does not provide any clear answer on this point. In our model, we have at least formalized the assumption by stating that there is a critical resource L that constrains the firm. But if one imagines an extension to the model wherein L can be increased over time, and if one maintains the assumption of never-ending intermediate economies of scale, then it is clear that the lowest cost configuration would involve one very large x producer, one very large y producer, and a host of final good producers that buy both x *and* y in the intermediate goods market. Of course, this immediately raises the question of how prices are set in this market.

We believe that the empirical evidence suggests that this assumption is about right. In the early years of an industry, the intermediate goods producers cannot grow large enough to create a monopoly. But if an industry produces substantially the same good with substantially the same technology for a long enough period, it does appear that there is a tendency toward consolidation. It seems that only antitrust enforcement prevents the last few mergers that would support a monopoly.

Stigler's Process model concerns the particular pattern in which firms specialize. We have formalized that model here. In particular, we have argued that intermediate scale economies create the incentive to specialize. This is close to Stigler's result. However, we do not find any reason to believe that the process by which this specialization occurs is efficient. Since specialization requires the cooperation of multiple firms, it is generally not possible to rule out multiple equilibria. Indeed it appears to us that strictly speaking, a purely vertically integrated industry is always a Nash equilibrium since no one firm can profitably specialize on its own.

We plan to extend the model in several ways. The most important is to examine the idea of an equilibrium configuration more closely. 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.

Also, 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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