

INTRODUCTION

Michael Gort's Contribution to Economics*

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Accepted January 1998

1. INTRODUCTION

The far-reaching influence of Michael Gort's work is only now becoming fully apparent. After getting his Ph.D. at Columbia University in 1954, Gort spent three years on the research staff at the National Bureau of Economic Research, a small, tightly knit group in those days. Since then, Gort's work has consistently been in the best Bureau tradition, which, I would say, aims "[t]o bring relevant, sound evidence to bear on interesting economic questions." To work in this tradition one must use economic theory to select appropriate data and procedures, and having done so, understand the quality of the data and the limits to which conclusions can be pushed. Proceeding in this way, Gort has measured economic magnitudes not previously measured (for example, organizational learning) and he has estimated parameters not previously estimated (for example, the effect of vintage of capital on productivity).

The unifying theme of Gort's work (and the theme of the papers in this volume) is technological change—its nature and its impact on other variables. For example, in his study of diversification Gort examined technological linkages between a firm's base industry and those into which it diversified. His work on mergers dealt with the impact of economic shocks (including technical change) on dispersion in valuations and, hence, merger frequencies. Gort's study of the diffusion of innovations and of firm survival rates established a systematic product life-cycle and some of

* I thank many colleagues for comments, especially Zvi Griliches and Glenn MacDonald.

its attributes. Finally, his work on productivity examined the role of learning by doing, of capital and organization learning, and the impact of vintage of capital on productivity.

The papers in this volume relate to many of Gort's ideas, and the authors have noted it where appropriate. Rather than repeat what they have said, I shall simply summarize a few of my favorite Gort papers. These papers fall into three areas: firm and industry dynamics, productivity growth, and mergers. I shall now discuss them in turn.

2. FIRM AND INDUSTRY DYNAMICS

2.1. *The Life-Cycle of Industries and Firms*

Gort's 1982 paper with Klepper [20] is arguably his most original. It inspired dozens of papers on the industry "life-cycle." Gort and Klepper documented the historical development of 46 products in terms of their sales, price, output, and numbers of producers over (a part of) the life of each product. Their study generated the following stylized facts:

(i) *Industry Sales and Output*: Sales and output of a product grow at a rate that declines rapidly with that product's age, and the rate tends to converge to zero.

(ii) *The Price of the Product*: Product price declines fairly steadily and at a decreasing rate as the product ages.

(iii) *The Number of Firms*: After the product is "born," first there is a rapid entry of firms, then a mass exit (a "shakeout"), and finally a stabilization in the number of firms at a level of about 40% below the peak number.

(iv) *Innovation*: Patenting does not fall off as the industry matures. Inventive activity does not seem to decline with the age of the product, although it appears that those innovations occurring while the product is young matter more than those occurring later.

A particularly graphic example is the historical development of the U.S. automobile tire industry, which is illustrated in Figs. 1 and 2.¹

With Agarwal [1], Gort has since added two more facts:

(v) A firm's exit hazard declines with its age.

(vi) A firm's exit hazard rises with the age of the industry.

¹The figures are based largely on the Gort-Klepper data and are taken from Jovanovic and MacDonald [26].

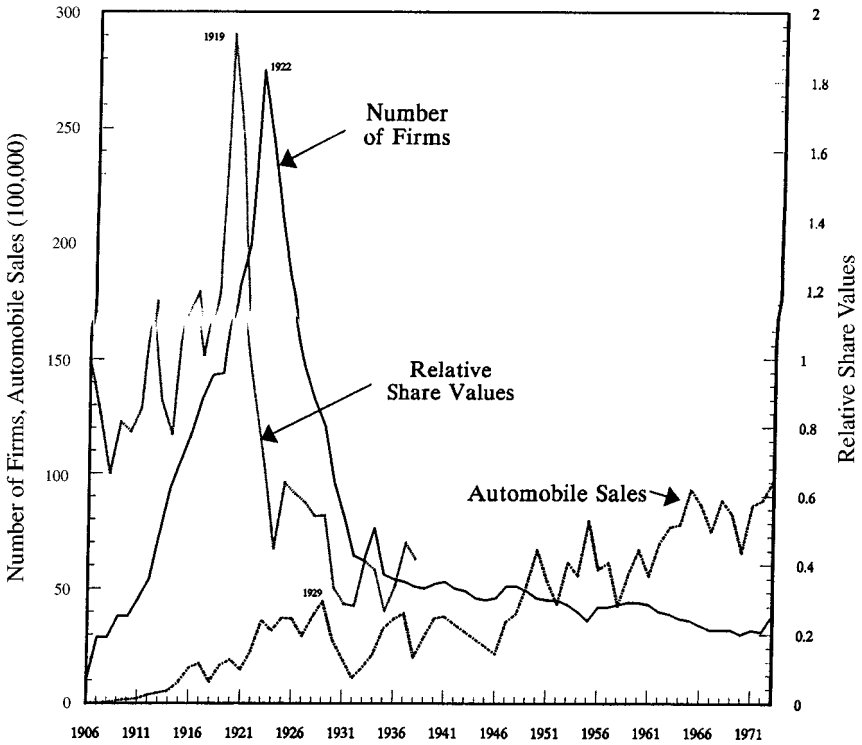


FIG. 1. Number of firms and relative share values in the U.S. automobile tire industry, and automobile sales.

These facts greatly add to our understanding of how a market works from birth to maturity. Briefly, fact (v) suggests that older incumbents are more efficient. Fact (vi) implies that the threshold of efficiency for viable operation in the industry rises as the industry matures. Fact (ii) implies a rising threshold and it also implies that as an industry ages, its incumbents as a group become more efficient—whether by learning, or by selection, or, as fact (iv) suggests, through ongoing technological process. Fact (iii) implies that in spite of the decline in the price of output, entry occurs at least until the onset of the shakeout—the declining product price does not deter entry—so that one can infer that each successive vintage of entrants is better than the previous one.

Fifteen years later, the Gort–Klepper paper is still state of the art, and work on other data sets confirms its results. Things should get clearer still when more variables are included in the analysis. For example, net entry is

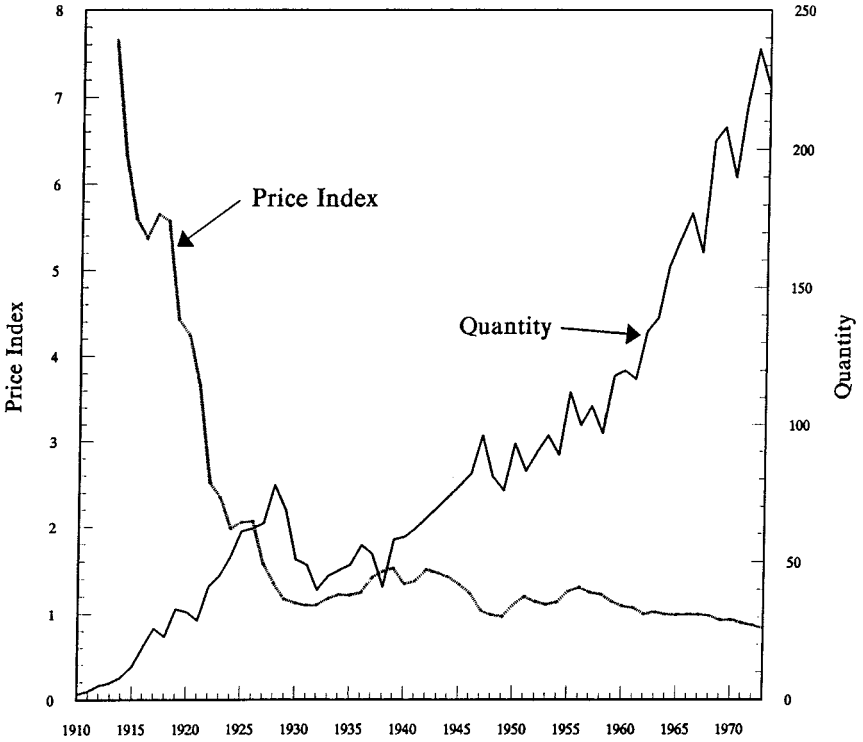


FIG. 2. Price and quantity in the U.S. automobile tire industry.

not the same as net capital formation, and a future refinement of the Gort–Klepper exercise will probably attempt to include measures of investment in physical and human capital.²

Gort and Klepper were not the first to discuss a “life-cycle” of products or industries. Kuznets [29] had studied the time series of the outputs and prices of 57 products, and found that their individual time series were well described by logistic curves, suggesting a product life-cycle. Moreover, most of Kuznets’ products displayed fact (i), and quite a few showed fact (ii) as well. So, had Gort and Klepper looked at each product’s output and price series only, their conclusions would have mirrored Kuznets’ and their work would not have had the impact that it has. But the scope of Gort and Klepper’s study was broader, for they looked at three other series for each

²Bessen [10] studies, by industry, the market share of entrants over a period of time as a proxy for the gross inflow of capital relative to market size that is due to entrants. He finds that this measure of capital inflow is strongly related to the TFP growth of the industry.

product: innovations, patenting, and, notably, “net entry”—the change in the number of firms from year to year.³ Indeed, the shift from Kuznets to Gort and Klepper is a shift from a “product cycle” notion that viewed an individual product as the unit of analysis to an “industrial organization” approach dealing with the endogenous evolution of industry. This shift occurred precisely because Gort and Klepper looked at numbers of firms and connected the age of the product to the evolution of the structure of its market. This led to a richer set of conclusions, and a richer set of empirical regularities for theorists to puzzle over. The early 1980s saw a wave of industry evolution models, and their authors increasingly tried to match Gort and Klepper’s facts, much the same way that growth theorists tried to match the development facts itemized by Kaldor [27].

2.2. *Collusion and the Instability of Market Shares*

Gort’s work on firm dynamics began much earlier, in his 1963 paper [17] on the stability of market shares. In the 1950s economists had begun the study of firm growth by exploring and testing the law of proportional growth, or “Gibrat’s law.” Gibrat’s law can be taken to imply that “firm size doesn’t matter” and that “organization is a veil,” and this work was interesting in its own right although it was confined to studying a single measure of firm size.

In his 1963 paper, Gort [17] infused economic content into the study of firm dynamics. He explored the idea that a high concentration ratio is less of a policy concern if there is a lot of turnover in the market shares of the firms at the top. Stability of market shares suggests collusion, especially if the concentration ratio is high and profits are above normal. Gort measured the market shares and profit rates of the 15 largest firms in each of 205 industries, at two dates seven years apart. He found that industries in which the leading firms’ market shares were more stable over this period did not show higher profits.

Apparently, then, if collusion existed in American industry, it did not stabilize market shares.⁴ Instead, as the Gort–Klepper work was later to show, the stability of market shares is likely to depend on the industry’s age, but it also showed that beyond a certain point the number of firms declines, so that it is the older industries that tend to be more concentrated.

³Kuznets had time series data on patents for six or seven of his products. Patenting shows little trend, tending first to rise and then to taper off a bit. This, more or less, is what Gort and Klepper found too.

⁴The volatility of market shares clearly is related to the volatility of plants’ investment rates over time and to its variability in the cross section, the topic that Doms and Dunne [13] study.

3. PRODUCTIVITY

3.1. *Learning at the Plant Level*

Bahk and Gort [5] is a comprehensive, and, so far, *the* definitive study of learning at the plant level. Before that, all we had were case studies.

Early tests of the vintage capital idea showed that new plants were not any more productive than old ones. Indeed, sometimes they were less productive!⁵ This was puzzling since new plants presumably embody cutting edge methods. The solution to the puzzle, of course, is that when built, a plant is about to start its climb up a learning curve. This is Bahk and Gort's message. They found that

(a) After controlling for investment and its vintage (to proxy for the quality of physical capital) and for changes in labor quality, the productivity of a plant rises for several years after its birth.⁶

(b) In estimates of 10 distinct production functions for 10 different age groups of plants, the explanatory power of the regression rises steadily with the age of the plants.⁷

(c) Technological change embodied in physical capital is associated with between 2.5 and 3.5% change in output for each 1-year change in vintage. Since they estimate that the coefficient of capital is 0.3, their procedure implies that obsolescence and depreciation of capital add up to between 8.5 and 11.5%.

(d) The elasticity of output with respect to wages (a proxy of labor quality) is 0.69. The elasticity of output with respect to employment is about the same, and so this suggests that efficiency units of labor can be summed into an aggregate.⁸

Assuming that they have controlled for changes in the quality of capital and labor, Bahk and Gort infer from finding (a) that a plant's "organiza-

⁵A recent incarnation of this finding is Aw, Chen, and Roberts [4].

⁶They study two balanced samples. Campbell [12] discusses section issues in a related context.

⁷Taken together, (a) and (b) suggest that low productivity firms are weeded out as they age, leaving a more homogeneous and more efficient group of survivors, and that reallocation of capital from exiting plants toward incumbents and entering plants is a source of growth. In support of this view, Baily, Hulten, and Campbell [6], Olley and Pakes [32], and Dwyer [14], working with plant data, and Griliches and Regev [23], and Aw, Chen, and Roberts [4], working with firm data, find that exiting units are less efficient than continuing ones.

⁸If the plant has monopsony power or if for some other reason the wage covaries with the shock to the production function, the coefficient of "quality" will be biased upward. However, in a series of estimates of production functions using regional data for U.S. agriculture and manufacturing industries, Griliches [22, Table 4] used a related index of labor quality (comprising wages and education) and reached much the same conclusion. At any rate, the wage variable has sizeable "explanatory" power: Dwyer [15] finds that variation in wages explains 15% of the interplant productivity dispersion.

tional capital" grows as the plant ages. This form of learning is disembodied from the two quality-adjusted inputs—it must be about the technology that is embodied in the plant itself,⁹ not in the machines installed as the plant ages. Clearly, a useful refinement of the Bahk–Gort work is to see how much learning is about specific types of equipment, how much is embodied in workers, and how much of *that* component of learning is specific to the plant.¹⁰

3.2. *The Aggregation of Physical Capital*

The legitimacy of aggregating capital services has occupied theorists on both sides of the Atlantic since the 1950s, and Gort was among the first to examine the issue empirically. To this day, the usual procedure is to either

- (i) combine all capital goods into a single stock by linearly combining past investments, with the weights depending on physical depreciation and on an estimate of the quality of the capital,¹¹ or
- (ii) assume a separate production function for each vintage of capital.¹²

Gort and Boddy [19] point out, however, that over 90% of equipment investment outlays go to install equipment in old structures (i.e., plants). Since structures are on average older than equipment, the productivity of new capital therefore depends on how it interacts with old capital. Gort and Boddy estimate a production function for electric power in which the interaction between new and old capital is positive, and this is inconsistent with both (i) and (ii). Their work foreshadows later elaborations of the vintage capital model that allow the rate of substitution in production between old and new capital to vary.¹³

4. DIVERSIFICATION AND MERGERS

Gort [18] argues that mergers are often prompted by a shock such as a change in technology. When the arrival of an invention changes how a firm

⁹As it is in Dwyer's [14], Klenow's [28], and Yorukoglu's [37] papers in this volume, provided that a firm's technological "update" requires that a state-of-the-art plant be built.

¹⁰Bahk and Gort [5] interpret human capital to be general, and hence well measured by the wage, as in Andolfatto and MacDonald [2], where all learning is embodied in labor. By this measure, labor quality grows as the plant ages, especially in the high productivity-growth plants [11].

¹¹Andolfatto and MacDonald [2] do this for both physical and human capital.

¹²Solow [35] did this, and so do the papers in this volume by Campbell [12], Klenow [28], and Jovanovic [25]. In Yorukoglu's paper [37] the production function and the adjustment cost function for equipment depend on the vintage or rather age of the *plant*.

¹³Such as Benhabib and Rustichini [9] and the papers by Dwyer [14] and Yorukoglu [37] in this volume.

should be organized, those that realize this first, or that can implement the changes best, may be outsiders. For instance, if a firm invents a product but lacks the expertise to develop it, a merger can provide the expertise. If an outside expert values the firm more than the insiders do, he may take it over and reorganize it. So, a firm that has the human capital or, perhaps, the financial resources needed to implement a new technology may merge with a firm that does not.¹⁴

Gort, Grabowski, and McGuckin [21] later refined this argument, focusing on the role of management. They argue that a management team is for various reasons indivisible, and when it experiences “slack,” it may try to take over another company and manage it. This seems to have happened in the beer industry in the sixties, seventies, and eighties, where mergers were a mechanism that got rid of excess management teams. Under this view of mergers, merger again serves to allocate a scarce resource—management—to sectors where it is needed most. Moreover, the indivisibility of management creates economics of scope in the sense that average production costs can be lowered by spreading the fixed management input over several products.¹⁵

These hypotheses emerge naturally from prior work by Gort [16], an extensive study in which he documents that mergers are more likely

(a) among firms that employ a higher technical to nontechnical personnel ratio,

(b) to involve a target in an industry characterized by rapid technological change,¹⁶ and

(c) to involve a target in a growing industry and an acquirer in a declining one, and hence to lead capital to flow faster from declining to expanding sectors.¹⁷ “The broadening of the investment horizon of individual firms is likely to increase the sensitivity of capital flows to differences in profit rates between industries” [16, p. 4].

Gort’s broader message is that mergers are a means by which capital—physical or human—finds its highest valued use. Now, one lesson from the Gort–Klepper paper is that as an industry ages, some firms will grow

¹⁴In support of this argument, Baker [7] notes that Beatrice Foods grew from a small company into a Fortune 500 conglomerate partly because it understood accounting practices invented at the turn of the century and introduced them in the businesses that it took over.

¹⁵Jovanovic [24] embeds this notion into Lucas’ [30] span of control model. A related information-theoretic model is Mitchell [31].

¹⁶Ueda [36] finds the merger-intensive industries experience high total factor productivity growth after a merger wave.

¹⁷Ravenscraft and Scherer [33] also find this. Output will be thus less volatile for the diversified firm, and related to this, Doms and Dunne [13] find that investment is smoother in larger plants, possibly because larger plants are more diversified.

and acquire capital, and others will die. The financial mechanisms used to accomplish this will depend on the type of industry. Acquisitions, spin-offs, initial public offerings, and private debt offerings are all ways to improve how capital is allocated, and the challenge for future work is to explain why a particular vehicle for capital reallocation is used in a particular circumstance—technological and informational.

Gort's study of mergers precedes two noteworthy developments. The first is the work of multiproduct firms and economies of scope, which, like Gort, stresses that diversified production can lead to gains in efficiency—a firm may be able to lower its costs not by specializing, but by diversifying its activities.¹⁸ The second development is the explosion of interest in explaining the relatively recent waves of mergers and downsizing.¹⁹ Real progress on this front is unlikely until we see a systematic study of the phenomenon—a study rivalling in quality and scope that contained in Gort's book [16].

5. A FINAL WORD

Michael always impresses me with his intellectual curiosity and his modesty. He rarely mentions his past work—he would rather tell you about his *next* project. Past work, he once said, will “speak for itself.” Well, this volume and the many references to Michael that it contains shows he was right!

Jeremy and I felt that a fitting tribute to Michael would be to gather, in one volume, the best new work on technological change. We think we've managed to do just that. We would like to thank each author for joining this project enthusiastically and for working hard to meet a tight schedule.

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¹⁸ Baumol, Panzar, and Willig [8] and, more recently, Smith [34].

¹⁹ A number of papers on the topic are gathered in Auerbach [3].

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