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Industrial concentration, price-cost margins, and innovation

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ABSTRACT

This paper explores a panel data set matching establishment-based production statistics from Japan's *Census of Manufacturers* with wholesale price indices from the Bank of Japan, and Herfindahl indices from the Japan Fair Trade Commission. The data include annual observations over the period 1961–1990, for 74 industries at the four-digit s.i.c. level. I estimate Cobb-Douglas production functions and Solow residuals for each industry and then use these estimates to further analyze the determinates of industrial concentration and innovation. The industries having great capital intensity and small employment of labor tend to be more concentrated. Cross-section estimates reveal a U-shaped mapping from concentration to innovation.

1. Introduction

This paper estimates the annual average rate of Hicks-neutral technical change in 74 Japanese manufacturing industries, 1961–1990, and relates these estimates to industrial concentration and price-cost margins. I do this by first estimating Cobb-Douglas production functions, under the maintained assumption of constant returns to scale. The residuals from these regressions measure technical change, and the labor coefficients measure labor's share in total cost for each industry. Price-cost margins are computed as the percentage by which value added minus total cost exceeds value of shipments (where total cost is the wage bill divided by the Cobb-Douglas labor coefficient). I find that the industries having great capital intensity and small employment of labor tend to be more concentrated. Industries with persistently high price-cost margins have no tendency to be either more concentrated or less concentrated than others. Cross-section estimates reveal a U-shaped mapping from concentration to innovation. Industry price-cost margins account for none of the cross-industry variation in innovation.

The data are drawn on four-digit s.i.c. industries, from Japan's *Census of Manufacturers*, for which wholesale price indices could be closely matched. These industries are defined as the sets of establishments – not firms – primarily producing like commodities. The close matching of the industries with corresponding wholesale price index categories affords a real output measure that is likely to be much more accurate than ones typically found in the empirical literature on production functions. That the data are observed at the industry level rather than the firm level poses aggregation issues which I do address. A strong point in the data is that, unlike firm-based micro-data, it allows us to precisely observe cross-industry variation at a fairly narrow (four-digit s.i.c.) level. Individual firms tend to be much more diversified than their constituent production establishments, and can often only be clearly assigned to industries at the two-digit level. Yet the theories relating industrial competitiveness or industrial concentration to innovation seem much more applicable at the four-digit level. The data used here also include annual time series of Herfindahl index of industrial concentration, matched from yet another source, the Japan Fair Trade Commission which is the antitrust enforcement agency of Japan.

Because the panel data set matches *establishment-based* measures of factor inputs, wages, revenues and value-added with *product-market* observations on prices and industrial concentration spanning three decades, it affords a particularly clear look at the cross-industry inter-relationship among industrial concentration, pricing, and innovation. Previous studies that have estimated a relationship between industrial concentration and innovation in Japanese manufacturing industries have relied on firm-level data. Okada (2005) estimated a common production function for a large sample of Japanese manufacturing firms, 1994–2000, that included average market share as an explanatory variable. Firms with larger

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average market shares seemed to be less productive, which led to the conclusion that more concentrated industries experience less growth in total factor productivity. Inui et al. (2008) estimated an equation explaining total factor productivity growth, measured by the index method, for each firm in a large sample of Japanese manufacturing firms, 1997–2000. They included as an explanatory variable each firm's weighted average three-digit s.i.c. Herfindahl index, with weights equal to fraction of the firm's own sales in each industry. They find that smaller Herfindahl index is associated with higher growth in total factor productivity and that this effect is greater, the smaller the Herfindahl index. The conclusion of Inui et al. matches that of Okada: less concentrated industries are more innovative. That is my conclusion also for industries with low concentration, four-digit s.i.c. industries with Herfindahl index less than 0.3, say. But for industries with Herfindahl indices above 0.3, there seems to be the opposite relation between concentration and innovation. The very highly concentrated industries are more innovative than the moderately concentrated ones.

2. Basic framework

I begin by addressing the aggregation issue. I will only observe production data at the industry level, and so must make assumptions about how the aggregate variables I observe are related to the firm-level variables I do not observe. The maintained hypothesis underlying my approach is constant returns to scale at the firm level.

Let us posit that each firm is constrained by a Cobb-Douglas production function with two inputs: labor and capital. Suppose further that the output elasticities of labor and capital are the same for all firms in the same industry, though total factor productivity may vary from firm to firm. Suppose also that firms in the same industry face the same factor prices and thus employ capital and labor in the same proportions to one another (I presume that all firms are equally adjusted to the same factor prices). Denote the production of firm f by

$$y_f = a_f l_f^{\theta} k_f^{(1-\theta)}, \tag{1}$$

where y_f = output, l_f = labor, and k_f = capital. Then, under my stated assumptions, the industry-level production function is

$$Y = \sum (z_f a_f) L^{\theta} K^{(1-\theta)} = A L^{\theta} K^{(1-\theta)}, \tag{2}$$

where $Y = \sum y_f$, $L = \sum l_f$, $K = \sum k_f$, and $z_f = k_f/K = l_f/L$.

The industry-level technology parameter, $\sum(z_f a_f) = A$, reflects both the firm-level technologies a_i and the allocation of factor inputs within the industry. So, for example, a technological change at the industry level ΔA comprises not only technical change by firms Δa_f, but also any changes in shares of the respective firms' employment of industry inputs that are induced through the posited oligopolistic equilibrium. The basic logic here is that of Zarembka (1968).

Another issue is how to measure industry output. I observe nominal shipments by each industry which I deflate by the corresponding wholesale price index. Take a moment to understand why this is a valid procedure. The wholesale price index p is approximately a weighted average of the prices of all the firms, with the weights corresponding to shares of physical output:

$$p = \sum \left(\frac{y_f}{Y}\right) p_f. \tag{3}$$

Therefore

$$\sum \frac{p_f y_f}{p} = Y. \tag{4}$$

Deflating nominal industry shipments by the wholesale price index affords a valid measure of industry output. DeSouza (2009) and others have noted that deflating each firm's nominal shipments by an industry-wide wholesale price index affords biased measures of each firm's output. Aggregation to the industry level as in the data used here avoids this bias and in that sense is actually a good thing rather than a problem.

A further serious issue in estimates of industry level production functions is identification. Specifically, when shifts in the production function are anticipated by firms, then they can be expected to adjust their employment of labor and capital. In this case the employment of labor and capital is correlated with the statistical error term in econometric estimates of the production function, and the estimated OLS coefficients are thus biased and inconsistent, as fully elucidated by Griliches and Mairesse (1998). Valid instruments for labor and capital might be found, particularly if one of these (capital) responds to productivity shocks with a lag. Then lagged values of capital become suitable instruments for contemporaneous employment of labor. This is the basic approach of the dynamic panel data literature (Olley and Pakes (1996), Blundell and Bond (2000), and Ackerberg et al. (2004)). But that literature focuses on micro-panel data, that is with many cross-sections but relatively few time periods. Typically the unit of analysis in such panel data is the firm, not, as here, the industry. A different way forward is needed. Again the maintained assumption of constant returns to scale is helpful.

First note that for the Cobb-Douglas production function as in (2) above for each industry:

$$Y = AL\left(\frac{K}{L}\right)^{(1-\theta)}, \tag{5}$$

and the identification problem is simply that of estimating the coefficient on K/L. That is, if businesses adjust their employment of both capital and labor *equally* in response to perceived productivity shocks, then endogeneity bias is absent. Notice that the maintained assumption of constant returns to scale is crucial to this. But is it plausible that employment of capital and labor would be equally flexible? Labor is typically regarded as a variable input and capital as fixed in the short run. However in Japanese manufacturing industries, the well-documented practice of lifetime employment should weaken this presumption. It is reasonable to suppose that Japanese manufacturers' employment of both labor and capital respond sluggishly to anticipated productivity shocks, mitigating the problem of endogeneity bias.

3. Econometric model

In the empirical literature on production functions, econometric specification is very much dependent upon the nature of the available data. Mine is a panel data set of calender year observations 1961–1990, for 74 manufacturing industries, including observations of average annual wholesale price index, Herfindahl index of production, and various establishment-based items including value added, value of shipments, employment, wages and book value of fixed tangible assets. All data were not available for all years so this represents an unbalanced panel data set. For a description of the data sources see Appendix A. One important aspect of these data has already been noted: They are aggregated to the four-digit s.i.c. level. Another thing to note is that I observe physical units of labor, number of employees, but only observe nominal units of capital, namely, book value of tangible assets. Accordingly, I will adopt a specification in which the multiplicative factor for converting units of capital from nominal book value to economically meaningful units of measurement is an estimable parameter. But before getting to that, an important