Capacity constraint and changing seasonality over business cycles: evidence from plant-level production data

Eiichi Tomiura*
Research Institute for Economics and Business Administration, Kobe University
2-1 Rokko-dai, Nada-ku, Kobe City, 657-8501, Japan

Revised: December 14, 2001
January 29, 2001

Abstract

The seasonal variability of production shrinks during a boom, not only at the industry level, but also at the plant level. Since this relationship is significant especially among plants with high capacity utilization, our finding is consistent with the capacity constraint hypothesis.

Keywords: Capacity constraint; Business cycles; Seasonality; Plant-level data

JEL classification: E32; D24; C49

* Eiichi Tomiura, Research Institute for Economics and Business Administration, Kobe University, 2-1 Rokko-dai, Nada-ku, Kobe City, 657-8501, Japan.
Tel: +81-78-803-7008; fax: +81-78-861-6434; e-mail: tomiura@rieb.kobe-u.ac.jp.

1. Introduction

The studies of interaction between seasonal variability and business cycles have been relatively limited, although they yield valuable insights into economic dynamics and seasonal adjustment methods. Among them, Cecchetti, Kashyap, and Wilcox (1997) suggested an important hypothesis that the seasonal amplitude of production is smaller during a boom because the capacity constraint forces firms to produce a larger fraction of output in off-peak seasons.[1] From the data of two-digit industries, they found empirical evidence to support this hypothesis. Since the capacity utilization considerably varies from plant to plant even within an industry, this paper reexamines their industry-level finding by exploiting newly constructed plant-level data.[2]

The remainder of the paper is organized as follows. Section 2 describes the data. Section 3 explains the empirical methods. Section 4 reports results from our sample. Section 5 concludes.

2. Description of data

As an example of production activity with strong seasonal cycles, this paper chooses the production of air conditioners in Japan. Data are derived from Japan's *Current Survey of Production* (Seisan Doutai Tokei, in Japanese).[3] This statistics contains data of production quantity and capacity in terms of physical units on a monthly basis.[4] This paper constructs a plant-level data set

---

[1] This holds true as long as the marginal cost curve is upward-sloping and convex. Cecchetti et al. (1997) consider marginal cost curves with various shapes.

[2] Beaulieu, Mackie-Mason, and Miron (1992) found a positive correlation between seasonal variation and nonseasonal variation in aggregate variables across countries and across two-digit industries. They attributed it to the capacity constraint since cross-section variability is smaller during a peak season because of the truncation of high output. Tomiura (1998) provided plant-level evidence for this interpretation. In this paper, the terms "plant" and "establishment" are used interchangeably.

[3] The classification code for the air conditioner in the *Current Survey of Production* is No.2180 in the Refrigerating Machines (No.18). The production quantity is measured by the number of outside units, while it is defined by the number of inside units for plants producing only the inside units.

[4] Although both Beaulieu et al. (1992) and Cecchetti et al. (1997) relied on deflated value data, the physical unit quantity data is preferable in our context since we analyze the capacity constraint. Krane and Braun (1991) used physical-unit data to test the production-smoothing hypothesis.

by obtaining access to the original confidential data files of the government.[5]

Table 1 shows that seasonal variability of production and of capacity utilization is substantially larger than cyclical variability. The figures from the same table also demonstrate how heterogeneous the plants in this industry are. Figure 1 illustrates that the within-year variation of aggregate production is milder in the boom year (1991-92) compared with that in the recession year (1993-94).[6]

3. Empirical methods

This paper adopts the same empirical methods as those employed by Cecchetti et al. (1997) to facilitate the comparison of results. First, consider the following reduced-form linear presentation of monthly production:

$$\ln Q_t - \ln \overline{Q}_t = \sum_{i=1}^{12} \sigma_i s_{it} + \sum_{i=1}^{12} \phi_i s_{it} \lambda_t \ , \qquad (1)$$

where the s_{it}'s are seasonal dummy variables (The i-th dummy is one if the month t is the i-th month of the year, zero otherwise.), λ is a measure of business cycle stage, and $\overline{Q}$ is the production level that would prevail in the average season if the business cycle were at a neutral position. Following Cecchetti et al. (1997), suppose that $\ln \overline{Q}_t$ consists of a linear trend and disturbance ν. This implies that production is supposed to be decomposed into time trend, seasonal and cyclical variations, including interactive terms, and error terms. Then, we can rewrite (1) to, after taking the

---

Besides, the use of micro data has advantage especially when we examine an industry composed of heterogeneous plants/firms. Schuh (1996), analyzing the aggregation effect in inventory models, is an excellent example of using micro data.

[5] Due to the confidentiality requirement imposed by the law, the data of individual plant cannot be made public. The plants are renumbered to keep anonymity. The sample period is from January 1988 to December 1995, to facilitate comparison with Tomiura (1998). Although 27 plants produced air conditioners during the period, six of them are excluded from our study of seasonality since they operated for less than two years.

[6] The year 1993-94 recorded the lowest level of production during our sample period, while the production was on the highest level in 1991-92. It is a custom in this industry to start a year

first-difference (Δ),

$$\Delta \ln Q_t = \alpha + \bar{\phi}\Delta\lambda_t + \sum_{i=1}^{11} \Delta\left\{\left[\left(\sigma_i - \bar{\sigma}\right) + \left(\phi_i - \bar{\phi}\right)\lambda_t\right]\left(s_{it} - s_{12t}\right)\right\} + \Delta \nu_t \qquad (2)$$

,where α corresponds to the slope of the linear trend in $\ln \overline{Q_t}$, while $\bar{\sigma}$ and $\bar{\phi}$ denote the means of the σ_i 's and of ϕ_i 's, respectively.

This paper estimates the equation (2) for each plant by using the monthly micro data and examines the following issues.[7] First, this paper tests the conventional assumption of $\phi_i = \bar{\phi}$ for every month i. If we impose this constraint, we neglect the interaction of seasonal variability with business cycles. We will report the test statistics *F* for the F test of the hypothesis that $\phi_i - \bar{\phi}$ (i=1, 2, … , 12) are jointly equal to zero.

Second, this paper investigates whether the seasonal variability tends to be larger or smaller during booms, based on the following summary measure which is borrowed from Cecchetti et al. (1997):

$$\Re = \frac{\sum_{i=1}^{12}\left[\left(\sigma_i - \bar{\sigma}\right) + \left(\phi_i - \bar{\phi}\right)\lambda^H\right]^2}{\sum_{i=1}^{12}\left[\left(\sigma_i - \bar{\sigma}\right) + \left(\phi_i - \bar{\phi}\right)\lambda^L\right]^2} \qquad (3)$$

,where λ^H and λ^L are the means of all observed values of λ_t above the 85th percentile and below the 15th percentile of λ_t, respectively. We expect this ratio less than one if the seasonal variability is less pronounced at a relatively high point in the business cycle.

4. Results from plant-level data

Our principal results are summarized in Table 2. First, the regression based on aggregated data confirms the previous results from two-digit industries by Cecchetti et al. (1997). Since the null hypothesis of all the interaction coefficients jointly equal to zero is rejected at any conventional

---

("refrigerating year") from September.

confidence levels, seasonal and cyclical variations are significantly interacted. Besides, the seasonal amplitude of production decreases during a boom because $\Re$ is substantially less than one.

Second, the results from plant-level regressions show that $\Re$ is less than one in 15 out of all 21 plants and that F test of no interaction is significantly rejected for 13 plants. Therefore, our analysis implies that seasonal variability and business cycles are interacted and that seasonal production variability tends to be milder during a boom at the individual plant level.

Finally, from Table 3, we find relatively high average capacity utilization rate for the plants whose seasonal production variations shrink during booms, especially whose interactions of seasonal and cyclical variations are significant.[8] Compared with the intertemporal or cross-section variability reported in Table 1, the contrast demonstrated in Table 3 is substantial. Hence, our plant-level finding is consistent with the capacity constraint hypothesis, which indicates that the capacity constraint attenuates seasonal production variability during a boom.[9]

5. Concluding remarks

By using plant-level data, this paper has confirmed that the previous result from two-digit industries is not the artifact of aggregation. The use of capacity utilization data has provided evidence for the capacity constraint hypothesis. As the interaction between seasonal and cyclical variation appears to be related with the degree to which the capacity can be adjusted, an important task left for future research includes the comparison of industries which have different capacity adjustment costs.

---

[7] This paper uses the total index of industrial production for λ, after detrended and deseasonalized.

[8] To examine the capacity constraint hypothesis, Cecchetti et al. (1997) use inventory data jointly with production data, while this paper exploits capacity utilization data. These two approaches should be interpreted as complementary.

[9] Excluding eight plants which stopped production during low seasons, identified by asterisks in Table 2, will rather reinforce the contrast.

Acknowledgments

Valuable comments from an anonymous referee are acknowledged. The access to the original micro-data files in the government of Japan was allowed by the General Coordination Agency as No.403 on December 6, 2000. Kazuyuki Motohashi, Makoto Kasahara, and Takanori Sakamoto of the Ministry of Economy, Trade and Industry helped me handle the micro data. The research was partly financed by the Grant-in-Aid for Scientific Research No.13630056. All remaining errors are mine.

References

Beaulieu, J.J., J. Mackie-Mason and J. Miron, 1992, Why do countries and industries with large seasonal cycles also have large business cycles? Quarterly Journal of Economics 107, 621-656.

Cecchetti, S., A. Kashyap and D. Wilcox, 1997, Interaction between the seasonal and business cycles in production and inventories, American Economic Review 87, 884-892.

Krane, S. D. and S. Braun, 1991, Production smoothing evidence from physical-product data, Journal of Political Economy 99, 558-581.

Schuh, S., 1996, Evidence on the link between firm-level and aggregate inventory behavior, Finance and Economics Discussion Paper Series 1996-46, Board of Governors of Federal Reserve System.

Tomiura, E., 1998, Correlation of seasonal variation and nonseasonal variation of production at the establishment level, Economics Letters 59, 201-205.

Table 1

COMPARISON OF VARIABILITY

	Across Months	Across Years	Across Plants
Production quantity	181556	108631	31899
Capacity utilization	0.168534	0.097586	0.139214

Note: The figures in the “Across Months” column are standard deviations among each month’s averages, while those in the “Across Years” are standard deviations among each year’s averages. These first two columns are based on data aggregated over all plants in our sample. The figures in the “Across Plants” column are the cross-section standard deviations across each plant’s averages. The capacity utilization is defined as the production quantity divided by the production capacity.

Table 2

TEST STATISTICS

	$\overline{R}^2$	F	$\Re$
INDUSTRY	0.924	4.676	0.198
PLANT 1	0.768	2.392	0.141
PLANT 2	0.857	3.124	0.263
PLANT 3	0.537	2.366	0.240
*PLANT 4	0.669	3.057	0.540
PLANT 5	0.610	3.056	0.118
PLANT 6	0.765	2.881	0.291
PLANT 7	0.615	2.553	0.189
PLANT 8	0.435	2.816	0.058
*PLANT 9	0.352	3.287	0.909
*PLANT 10	0.477	1.885	0.753
PLANT 11	0.477	0.811	0.358
PLANT 12	0.542	1.813	0.037
PLANT 13	0.627	1.270	0.174
PLANT 14	0.297	1.443	0.106
*PLANT 15	-0.042	1.011	0.139
*PLANT 16	0.608	8.155	4.236
*PLANT 17	0.561	10.51	4.033
*PLANT 18	0.576	20.12	2.212
*PLANT 19	0.195	2.732	1.290
PLANT 20	0.014	0.392	4.097
PLANT 21	0.457	0.693	2.970

Note: The "INDUSTRY" row corresponds to the data aggregated over all the plants. The asterisk identifies the plant which stopped production during low seasons. $\overline{R}^2$ is the coefficient of determination after degree of freedom adjustment for the regression (2). F denotes the test statistics for the hypothesis of all the interactive terms ($\phi_i - \overline{\phi}$) jointly equal to zero in (2). $\Re$ is a measure of seasonal production variability during booms relative to that during recessions, defined by (3).

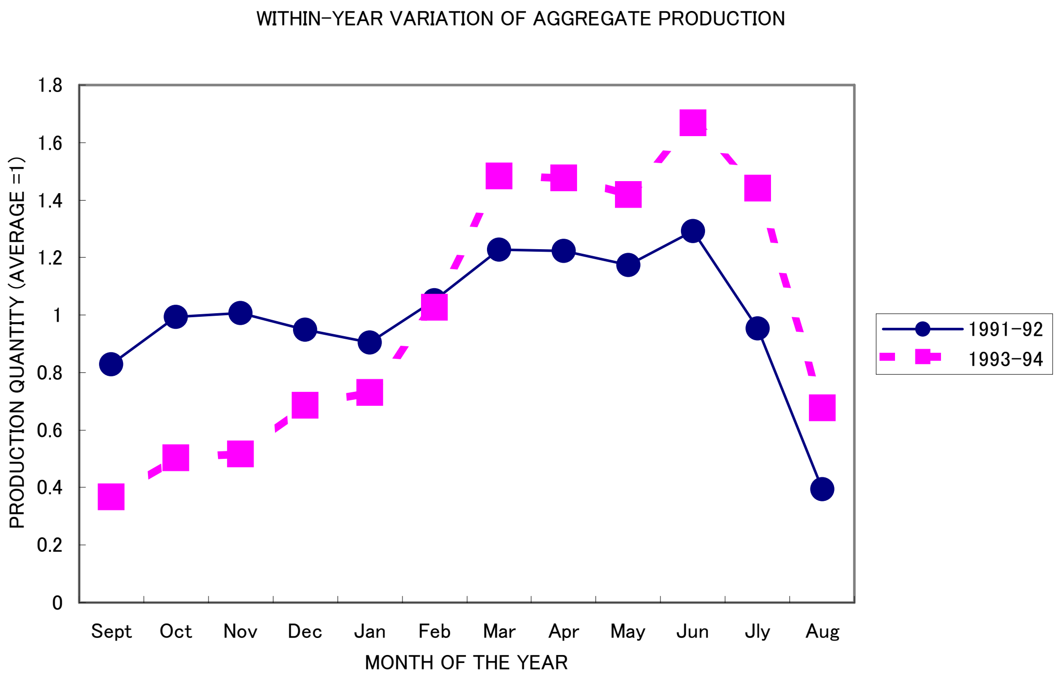
Table 3

AVERAGE CAPACITY UTILIZATION RATES OF PLANTS

	Plants with ***significant*** interaction of seasonality and business cycles	Plants with ***insignificant*** interaction of seasonality and business cycles
Plants with ***smaller*** seasonal variability during a boom	0.4642	0.4379
Plants with ***larger*** seasonal variability during a boom	0.3614	0.2069

Note: The upper-left box corresponds to the unweighted average of capacity utilization rates over plants No.1 to 9 (plants with $\Re < 1$ and $F > 2$), according to the numberings in Table 2. Similarly, the figures appeared in the upper-right, the lower-left, and the lower-right are the average of plants No.10-15 (plants with $\Re < 1$ and $F < 2$), No.16-19 (plants with $\Re > 1$ and $F > 2$), and No.20-21 (plants with $\Re > 1$ and $F < 2$), respectively. The capacity utilization rate is rescaled so that the maximum during the period is equal to one for each plant.

FIGURE 1



Note: The monthly aggregate production quantity, measured on the vertical axis, is standardized so that the average in each year is equal to one.