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Non-convex costs and capital utilization: A study of production scheduling at automobile assembly plants☆

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Abstract

I study detailed data from eleven automobile assembly plants. These data display considerable cross-plant heterogeneity in production scheduling. To explain the observed heterogeneity, I solve a dynamic programming model. When desired production is below the plant's minimum efficient scale, non-convexities induce production bunching; the plant uses less than full capital utilization on average and production is more volatile than sales. When desired production is above the plant's minimum efficient scale, the plant operates in a convex region of the cost curve. In this case, it uses high levels of capital utilization and production is less volatile than sales. © 2000 Elsevier Science B.V. All rights reserved.

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1. Introduction

This paper studies how managers at automobile assembly plants organize production across time. I formulate and solve a dynamic programming model that explains the production behavior observed from a new plant-level dataset. The model incorporates two non-convex margins: the adding and dropping of an additional shift and the shutting down of the plant for a week at a time. These non-convex margins play a central role in explaining much of the heterogeneity in production scheduling observed in the data. Specifically the model predicts that when sales are below the plant's minimum efficient scale (MES) managers will use primarily non-convex margins to adjust output.[1] Thus production will be more variable than sales, and the plant's capital will sit idle much of the time. In contrast, when sales are above the plant's MES, managers will use convex margins to adjust output; this production behavior is consistent with production as variable as sales and high levels of capital utilization.

I study a new database of fourteen automobile assembly plants. Eleven of these plants are the sole producers of various vehicle lines. For these eleven plants, weekly capital utilization and production date can be accurately aligned with monthly employment, inventory, and sales data. These data display three facts that a successful model of automobile production should capture.

1. For the average plant the workweek of capital is just 66.8 h. More striking though are the differences in capital utilization across plants. While the average workweek of capital for some plants is close to 100 h, it is less than 15 h at other plants. Yet at all the plants the nominal premium for night work is modest, and the costs of having idle workers on the payroll are large. Workers on the second shift receive only about 5% more than workers on the first shift. Laid-off workers from these plants receive 95% of their straight time wage plus benefits.

   Puzzling low levels of capital utilization are not unique to the auto industry. The capital stock in U.S. manufacturing industries is employed, on average, fewer than 60 h per week (Shapiro, 1995). Shapiro argues that the true marginal premium for second shift work is closer 25%. Although this higher marginal shift premium partially resolves the puzzle, the question still remains: Why does the capital stock at some of these plants sit idle so much of the time?
2. At the average plant, the standard deviation of monthly production 21% larger than the standard deviation of sales. However, this production pattern is not uniform across all the plants. At some plants production is about as volatile as sales, while at other plants production is much more volatile than sales.

[1] The minimum efficient scale is the level of output that minimizes average cost.