Do Flexibility and Chaining Really Help? An Empirical Analysis of Automotive Plant Networks

1. Introduction

In their seminal paper, Jordan and Graves (1995) demonstrated that long chains are as effective as fully flexible systems in manufacturing networks: by creating limited flexibility using long chains, automotive firms are better equipped to face demand uncertainty and maximize capacity utilization. They also provided a novel metric to measure flexibility. Since then, the effectiveness of long chains have been well established in the literature. Therefore, common wisdom suggests that we should be able to observe more and more long chains in the automotive industry. In contrast, recent real-life manufacturing networks of automotive assembly plants of three major USA (Chrysler, Ford and General Motors) indicate the opposite trend. Despite benefits of flexibility, these companies have configured their networks to be less and less flexible. Thus, more models are being produced in dedicated plants. As illustrated in figure 1, Chrysler was manufacturing seven models in more than one plant in 1998, which dropped to three in the year 2006, with the network configuration not resembling long chains, representing an empirical puzzle.

![Figure 1: Chrysler production networks in 1998 and 2006](image)

Several other flexibility indices were developed in the literature but never tested in an empirical setting. Motivated by this research gap and counterintuitive behavior of the companies,
we study production networks of automotive assembly plants to shed new light on the impact of flexibility and network structure on plant performance. In this work, we identify potential limitations in the existing flexibility indices and we propose two new indices aimed to better measure flexibility. Our dataset consists of plant level data for 70 assembly plants across three companies for the years 1998 to 2006.

There are three major contributions of our work: (1) For the first time, we reconcile the extant empirical and modeling literature by testing existing flexibility indices; (2) We introduce new flexibility indices to assess the relationship between flexibility and productivity to explain the trend of real-life networks; (3) We empirically show that intermediate levels of flexibility are optimal due to trade-off between better flexibility and productivity, however, chaining may not be the optimal configuration if changeover losses of flexible plants are accounted for.

2. Model

We fit a linear econometric model using OLS. We use labor productivity (vehicles produced per labor hour) as our dependent variable. Our treatment variables are various flexibility indices. We control for several variables in the plant, which are known to impact productivity such as installed capacity and number of platforms produced. To account for time invariant plant level heterogeneity we employ plant fixed effect. Variables such as taxation and pollution standards, which vary annually, are controlled using year fixed effects. To address the autocorrelation between the observations of the same plant, we estimate clustered standard errors at plant level. Our identification strategy relies on the fact that, if we control for various parameters (including unobservables through fixed effect), we should be able to identify the impact of flexibility on plant performance. To adjust standard errors in estimation due to non-independence of observations we use clustered standard errors at plant level.
To address potential endogeneity issues in identification, we employ instrumental variable to re-estimate coefficients using 2SLS model. We identify models in production by competitors as a valid instrument and results turn out to be consistent with intuition. We use data sets for the weekly plant production schedule to identify the potential mechanism behind our results.

3. Main Results

Our results suggest that the relationship between flexibility and productivity is more nuanced than currently addressed in the modeling literature. By construction, different flexibility measures will result in different relationship with plant performance. Consequently, using our proposed flexibility metrics we find that there exists an inverted U-shaped relationship between productivity and flexibility. This indicates that both extremes of flexibility (too much or too little) impact productivity negatively. Therefore, intermediate levels of flexibility are optimal as they balance the trade-off between better matching of supply and demand with excessive downtime due to model changeovers.

Our counterfactual and simulation results show that a firm can improve productivity by re-configuring its network. Counterintuitively, firms can not only gain productivity by increasing flexibility, but also by reducing it contingent on the current level of flexibility in the network. Thus, flexibility can be thought as a new lever to improve productivity by reducing wasted labor hours in manufacturing. Our estimations indicate that a firm with an extremely flexible production network can gain up to 8% in productivity through rearrangement of its network. This can result in an average saving of 418 thousand labor-hours in a plant with average production of 200 thousand vehicles per year.

4. References
