Supply Chain Proximity and Product Quality

(Authors’ names blinded for peer review)

We estimate the effect of supply chain proximity on product quality. We combine four automotive datasets at the product level, collecting data on: (i) auto component defect rates, (ii) upstream component factory locations, (iii) downstream assembly plant locations, and (iv) product-level links connecting the upstream and downstream factories. Using these data, we trace the flow of 27,807 products through 529 supplier factories and 275 assembly plants. We estimate that increasing the distance between an upstream component factory and downstream assembly plant by an order of magnitude increases the component’s expected defect rate by 3.9%, and also that quality improves more slowly across geographically dispersed supply chains. We also find that supply chain distance is more detrimental to quality when automakers produce early-generation models or high-end products, when they buy components with more complex configurations, or when they source from suppliers who invest relatively little in research and development.

Key words: Quality Management, Empirical Operations, Supply Chain Management, Geographic Proximity

1. Introduction

Proximity of upstream and downstream production plants should improve product quality. Geographic proximity facilitates communication and oversight, and shortens response times:

    Proximity is not just a physical relation, but also, and in some cases mainly, a service relation .... When suppliers are located next to the assembler’s plant, it is easier for them to act when there is any quality problem concerning the component in the assembly line .... Proximity is mainly a way to decrease risks—deliverance problems, quality problems (Salerno et al. 1998, p. 151).

However, there is little empirical evidence of a relationship between supply chain proximity and product quality. And we know even less about the factors that moderate this relationship—for example, can managers alleviate the curse of distance by acquiring manufacturing experience, sourcing less-complex components, or from more R&D-intensive suppliers?

Studying the relationship between supply chain proximity and product quality is difficult because we require data on (i) a product quality metric, (ii) the location of the upstream factories, (iii) the location of the downstream assembly plants, and (iv) product-level links connecting the two factories. To circumvent this problem, we combine four independent automotive datasets which—despite their disparate origins—harmonize at the product level, allowing us to create one of the most detailed supply chain samples ever constructed:
• We derive a product quality metric with (i) NHTSA’s SaferCar dataset, which details 976,000 defect reports submitted to the federal government at the auto-component level, and (ii) IHS’s PolkInsight dataset, which reports annual U.S. vehicle registrations for all vehicle-year models. We measure auto part quality with the number of defect reports filed per vehicle years on the road. For instance, we observe that the 2002 Ford Fusion’s engine was the subject of 685 defect reports in 4,305,340 vehicle-years of drive time.

• We glean upstream factory locations from Bureau van Dijk’s Orbis database, which reports the whereabouts of 26,375 facilities spanning 14,798 auto component suppliers. For example, we observe that Valeo Sylvania, a supplier of the exterior lighting system, has factories in Seymour, USA (latitude 38.94, longitude -85.89) and Queretaro, Mexico (latitude 20.58, longitude -100.38).

• We determine downstream assembly plant locations with SupplierBusiness’s Who Supplies Whom (WSW) database, which reports the position of 275 assembly plants spanning 74 car brands. For example, we observe that Chevrolet has 25 assembly plants, including factories in Gravatai, Brazil (latitude –29.94, longitude –50.99) and Kansas City, USA (latitude 39.11, longitude –94.62).

• We obtain product-level links—connections between upstream and downstream factories—from the WSW dataset, which reports the buyers and suppliers of 171,000 distinct auto components. For example, we observe that Toyota installed 97 parts from Midway Products in the 2011 Corolla, including battery trays, child tether brackets, spring brackets, and rear stabilizers.

Combining these datasets yields a panel of 28,500 supply chains. For each, we observe (i) an auto component, (ii) an upstream component factory location, (iii) a downstream vehicle assembly location, and (iv) a defect rate. For instance, we observe that Infasco Nut produced fasteners for the 2014 Corvette in Mississauga, Canada (latitude 43.74, longitude –79.64); Chevrolet installed the part at their Bowling Green, USA plant (latitude 36.95, longitude –86.42); and customers filed 53 defect reports pertaining to this part over 1.363 million vehicle-years on the road.

In our panel, supply chain distance correlates positively with defect rates. But this summary statistic can be misleading because the supplier selection process makes the distance to the upstream factory endogenous—that is, both proximity and quality influence whether the supplier wins the procurement contract. We control for this sample selection bias in two ways.

First, since the endogeneity arises from the supplier selection process, we model this process explicitly with Dahl’s (2002) correction, which uses the unobserved characteristics of the supplier choice set as shifters for the unobserved quality of the chosen supplier.

Our second identification strategy exploits vehicle assembly relocations as quasi-exogenous shocks to supply chain distance. In our sample, the production of 79 car models moved from one assembly...
plant to another. These uprootings abruptly shifted the supply chain distances of the 2,451 components that comprise the 79 car models (53% of the supply chains lengthened, 47% shortened). We track how the defect rate of a given part from a given supplier changes when the automaker moves vehicle assembly from one plant to another, and we regress the difference in the defect rates, pre- and post-relocation, on the change in the supply chain distances, pre- and post-relocation.

Both approaches yield the same result: greater supply chain distance impairs product quality. Increasing the distance between an upstream component factory and downstream assembly plant by one order of magnitude increases the component’s expected defect rate by 3.9%. Put another way, replacing the current supply chain distance with the distance of the next-farthest supplier—a 1,271 km increase, on average—increases the expected defect rate by 1.57%–2.17%.

We also study the factors that mediate the relationship between supply chain distance and product quality, finding that distance is more detrimental to quality when automakers produce early-generation models or high-end vehicles, when they source a complex component (i.e., one with many subcomponents), when the supplier is located in another country, or when the supplier invests little in research and development. In this sense, Toyota should value proximity differently when sourcing the electrical system of the 2010 Lexus CT (a complex component of a first-generation, luxury model) than when sourcing the interior lights of the 2011 Camry (a simple component for a seventh-generation standard model).¹

Finally, we explore a hypothesis that explains our results: distance undermines collaboration, slowing quality improvement. In particular, we track the evolution of defect rates across multiple production years of a car model component. Our estimates show that while quality systematically improves over time for the average auto part, the rate of this improvement is inversely proportional to supply chain distance.

Our findings are timely because the auto industry is currently in a state of flux, with manufacturing clusters moving en masse from country to country. In fact, after surveying 42 automotive suppliers and automakers, Spindelndreier et al. (2015) found a full 97 percent of executives we interviewed agreed with the statement, “The relevance of manufacturing-network design will increase in the next five to ten years.” ... Asked to rate the most important reasons for adjusting their global production networks ... the second-most-important driver was proximity to end customers.

By quantifying the tradeoff between distance and quality, we empirically link the supply chain management and quality management literature, which we summarize next.

¹ The expected marginal effect of distance is three times larger in the first case than in the second.