

Where Do Automotive Suppliers Locate and Why?

JOB MARKET PAPER

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Abstract

Historically, automotive production in the U.S. was dominated by the domestic-owned assemblers (Ford, G.M., Chrysler) and the clear center of the industry was the Midwest. However, during the last 20 years, many foreign-owned assemblers (e.g., Honda, BMW) opened plants in the lower labor cost South. This change has created the potential for a new industry center in the South and raised concerns about the future of the industry in the Midwest. In order to understand the geography of this industry, I quantify three major factors driving supplier plant location: labor costs, distance costs, and fixed costs. I estimate the relative contribution of labor costs and distance costs to the variable cost of producing and delivering a given part. I find that, for foreign-owned suppliers, being in a right-to-work state decreases supplier costs by an amount equivalent to being 2,300 miles closer to the downstream assembler. For domestic-owned suppliers, this impact is equivalent to being only 200 miles closer to the downstream assembler. To assess the relative importance of fixed costs and variable costs in determining plant location, I simulate equilibrium supplier locations if plant location were determined only by variable costs. In this simulation, the geographic mean of supplier plants would be 290 miles south of its actual location in 2007.

JEL-Classification: L11, L14, L62, R12, J51

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1 Introduction

The economic activity of many industries is geographically clustered. Some of these clusters have remained in their historic locations, some have moved to new geographic locations, and some have broken apart.¹ The politically prominent and economically significant U.S. automotive industry is currently teetering between these three possibilities.² This industry's historic center in the Midwest is one of the most deeply embedded industrial clusters. However, during the last 20 years, foreign-owned assembler firms opened plants in the lower labor cost South, where, in comparison to the Midwest, there are lower unionization rates and laws that make unionization more difficult (right-to-work laws). These plant openings have raised that region's share of U.S. production from 6% in 1990 to 18% in 2008.³

In order to understand the industry's current geography and likely path for the future, I quantify three major factors driving the locations of automotive suppliers: labor costs, distance costs, and fixed costs. Using data on vertical contracting, I estimate the relative contributions of labor costs and distance costs (e.g., transport and just-in-time related costs) to the variable cost of supplying a given part. Then, by simulating equilibrium supplier plant locations, I recover the overall impact of fixed costs in determining the geographic locations of supplier plants.⁴ Distinct from previous work in this area, I separately identify variable and fixed costs using vertical contracting data and a model of supplier plant profits. I find that fixed costs and distance costs orient the industry towards its historic center in the Midwest, while labor costs orient the industry towards the lower labor cost South.⁵

I focus on the location decisions of automotive supplier firms. These firms, which employ hundreds thousands of workers in thousands of plants, employ more people in their plants than the automotive assembler firms do in theirs (Klier and Rubenstein 2008). Therefore, these firms have a large impact on whether the industrial cluster as a whole moves, stays, or breaks apart. These firms must choose whether to locate their plants near the center of production in the Midwest (with 51% of 2008 production), or to locate their plants in the lower labor cost South, near the foreign-owned assemblers.

To understand the motives driving these decisions, I use a two-period model in which

¹Dumais et al. (2002) show some evidence regarding industry differences in this regard.

²According to the Center for Automotive Research (2010), the automotive industry accounts for 3% of U.S. GDP and 4% of U.S. employment.

³For the purposes of this paper, "South" is defined as: Alabama, Georgia, Mississippi, South Carolina, and Tennessee. "Midwest" is defined as: Michigan, Illinois, Indiana, Ohio, and Wisconsin.

⁴"Fixed costs" in this context refers to anything other than variable profits that drive plant locations. In section 6, I discuss what could be included in these costs.

⁵Labor, logistics (e.g., proximity to assemblers), and location-specific fixed costs (e.g., site readiness) are listed in a trade magazine article as the three major factors to consider when locating an automotive supplier plant (Canup 2007).

assemblers choose suppliers and supplier firms locate plants. In the first period, supplier firms choose where to locate their plants to maximize their expected profits. In the second period, shocks to variable costs are revealed and supplier firms compete for contracts from the assemblers.

I recover costs from the data using this two-period framework. Working backwards, I estimate supplier variable costs using detailed data on which supplier firms sell parts for use in which car models.⁶ Using these variable cost estimates, I derive supplier firm variable profits and I simulate supplier firms' optimal locations. By comparing equilibrium plant locations when suppliers locate solely on the basis of variable costs to the observed plant locations in the data, I recover the role of fixed costs in driving plant locations.

Using the variable cost estimates, I compare the relative magnitude of labor costs and distance costs in determining suppliers' variable costs. Not surprisingly, being farther from a given assembler raises the costs of supplying that assembler. Further, this effect is larger for heavier parts and parts that are more likely to be supplied just-in-time. I also find that supplier costs are higher for plants located in a non right-to-work state.⁷ This effect is much larger for foreign-owned supplier plants than for domestic-owned plants. This difference is consistent with domestic-owned plants having a potentially costly cooperative relationship with the union, regardless of the state legal climate. Therefore, the state laws towards unions could be less relevant for the domestic-owned suppliers that are likely to have this relationship regardless of location. Comparing the magnitude of these costs, I find that, for a foreign-owned supplier, having a plant in a right-to-work state is equivalent to having a plant 2,300 miles closer to the assembler. For a domestic-owned supplier firm, these costs are equivalent to having a plant 200 miles closer to the assembler.⁸

In order to estimate supplier firms' expected profits in different locations, I estimate the cost-savings associated with supplier/assembler relationships. These estimates yield new evidence on the importance of upstream/downstream firm relationships. Suppliers have lower costs to supply a given assembler when the parent companies are headquartered on the same continent, have a historical relationship (e.g., were vertically integrated), or the assembler is a large percentage of a supplier's contracts globally. There is a large amount of heterogeneity in the importance of these benefits. For Asian assemblers and Asian suppliers, these benefits are equivalent to locating ten thousand miles closer together. However, for

⁶These data are the "Who Supplies Whom" (WSW) data from the consulting firm Supplier Business (now part of IHS) and covers the years 1999-2008.

⁷Right-to-work laws ban workplaces where employees are required to join a union (Holmes 1998). I will use the Department of Labor classification of these states. Results are similar when using a measure of the state unionization rate.

⁸As a benchmark, the distance from Detroit, MI to Mobile, AL (along the Gulf Coast) is 850 miles.

North American owned assemblers and suppliers, these benefits are equivalent to locating 1,200 miles closer together.

When I simulate the optimal locations of suppliers if supplier plants were to locate solely on the basis of variable costs, their geographic mean in equilibrium would be 290 miles south (farther from the Midwest) of its actual location in 2007. This finding illustrates the importance of fixed costs in driving the locations of supplier plants. Further, I simulate supplier plant locations for a case in which suppliers locate solely on the basis of distance costs. I find that given the 2007 locations of assembler production, the mean supplier location would have been in the Midwest. This indicates that the move South by assemblers was not sufficient to make locating in the South optimal from a distance cost perspective. However, if current trends by assemblers continue, this may change over time. I find that if suppliers located based on distance costs alone, doubling the 2007 share of production in the South would shift the equilibrium center of the industry 70 miles farther south.

In addition to assessing the magnitude of these costs, I conduct two counterfactual experiments to assess the impact of recent or proposed changes to the power of unions in this industry. Many politicians in the Midwest are trying to pass right-to-work laws in their states in order to make their state more attractive to manufacturing firms, including automotive suppliers (New York Times 2012b). Therefore, I simulate an environment in which the labor costs associated with unions in all states are equal to the union-associated costs in the current lowest cost state. I find that the overall reduction in the cost of producing parts would be equivalent to three times the reduction from eliminating all costs of distance (within the U.S.). In my second counterfactual, I simulate the impact of reducing the labor cost premium at domestic-owned supplier firms. During the 2011 contract negotiations between the United Auto Workers (UAW) and the domestic-owned assemblers, General Motors's labor costs were reduced to near parity with the foreign-owned assemblers (McAlinden and Dzielicki 2011). I simulate a reduction in the labor costs of domestic-owned suppliers to parity with foreign-owned suppliers, finding that the overall reduction in the cost of producing parts would be equivalent to eight times the reduction from eliminating all costs of distance (within the U.S.). For reasons that will be discussed in section 2, distance costs are important in this industry. Therefore, the magnitude of these results highlights the important role of unions in determining costs and plant locations in this industry.

Models of industrial plant location have been a standard framework for studying the impact of local labor market policies and distance costs, both in general and in the automotive supplier industry. Using a discrete choice model of plant location across states, Bartik (1985), Klier and McMillen (2008), and Florida and Smith (1994) (the last two focus on automotive suppliers) find that states with high unionization rates have less manufacturing

activity.⁹ These location choice models also show that suppliers are more likely to locate near assemblers, where “near” is defined as assembler presence within a given radius.¹⁰

The modeling approach in this paper adds to the previous literature in at least two ways. First, the location choice framework used in previous work treats each plant location decision in isolation. In contrast, I account for the interdependence of supplier plant locations both within and between firms. Second, the two-stage modeling framework allows me to separately identify the impact of fixed, labor, and distance costs on supplier plant location. This is not possible in the location choice framework used in earlier work, where firm preferences over locations are not derived from a model that distinguishes between fixed and variable costs.

The ability to separately identify variable from fixed costs is enhanced by my use of vertical contracting data. Since I assume contracting efficiency (i.e., the low-cost firm wins the contract), data on “who supplied whom” gives information regarding firms’ variable costs. This obviates the need for a more complicated model in order to separate variable from fixed costs and to separate different components of variable costs (e.g., labor and distance costs) from each other. To my knowledge, this use of vertical contracting data in order to recover variable costs is new.

The two-stage model that I use is similar to many entry models in the empirical industrial organization literature, in that firms first decide where to enter and then compete in product markets. One important difference is that the profit function in this paper is derived from primitive assumptions on competition. This is in contrast to much of the literature, which uses a profit function that is linear in the number of competitors and is not derived from economic theory.¹¹ Another way in which I depart from the entry literature is in my equilibrium concept. In many models used in the empirical entry literature, the set of Nash equilibria in the location stage is typically large (Berry and Reiss 2007). I use the cost-minimizing Nash equilibrium as the equilibrium concept for the location stage of the game.¹² Using the profit function from the model, this cost-minimizing Nash equilibrium can be found by minimizing

⁹Holmes (1998) is one notable exception to this discrete choice approach. Using a boundary discontinuity style method, he finds a decline in the proportion of employment in manufacturing when crossing a state border from a right-to-work to a non right-to-work state. There is also a literature looking at the impact of unionization using a regression discontinuity approach with data on close unionization elections (Lee and Mas 2012; Sojourner, Town, Grabowski, and Chen 2012; DiNardo and Lee 2004). These regression discontinuity papers isolate the causal impact of a single plant’s unionization at the plant where it occurs. In contrast, the other papers cited assess the impact of having a plant in a region with different union prevalence, which could impact the plant through the possibility of unionization regardless of whether or not the plant is unionized.

¹⁰In their book on the automotive supplier industry, Klier and Rubenstein (2008), using descriptive analysis, note that while many supplier plants are located “nearby” (within hundreds of miles) to an assembler they are not located “next door” (within tens of miles). However, given the data and methods used in the book, they are not able to be more precise about these descriptions.

¹¹A recent exception is Eizenberg (2011).

¹²It is not needed to recover the variable costs parameters in the procurement stage.

a single function, bypassing the need to solve for multiple equilibria.¹³

The paper proceeds as follows: section 2 provides industry background, section 3 details the model, and section 4 introduces the data. Section 5 discusses the estimation of the variable cost parameters, while section 6 discusses the simulations of equilibrium supplier plant locations. Section 7 contains the counterfactual exercises and section 8 concludes.

2 Industry Background

Many of the parts used by the major automobile manufacturers (referred to in this paper as assemblers) to produce cars come from a large network of suppliers. These suppliers are frequently categorized into tiers, reflecting their locations in the “river” of production. The suppliers that supply the assembler directly are known as tier-one, the suppliers that supply the tier-one are tier-two, and so on. A supplier could be a tier-one for one car model and a tier-two for another.

Contracts between an assembler and a tier-one supplier are typically made through a competitive bidding process.¹⁴ These contracts are typically put up for bidding at the introduction of a new car model, and the contract will last for the duration of the model, typically 4-8 years. While the contract is usually long-term, the purchase orders for specific quantities and prices are negotiated on a more short-term basis.¹⁵

Even though contracts are usually tendered on a per-model basis, many suppliers have assemblers with whom they frequently do business. Many times these relationships will be with firms from the same country, which could reflect relationship-specific human capital or a common corporate culture leading to shared expectations about proper business methods.¹⁶ However, even while many supplier firms have “primary customers”, supplier firms typically attempt to have a diverse portfolio of assemblers that they supply, and try to obtain contracts from a range of different assemblers (Jauchius et al. 2004). Typically, even from a given plant, suppliers will supply multiple assemblers.¹⁷

The importance of the geographic proximity of suppliers to assemblers is a result of

¹³Other solutions in the literature to the multiple equilibria problem include aggregating outcomes (Berry 1992), assuming sequential moves by players (Mazzeo 2002), and considering outcomes from *possible* equilibria in the counterfactual after set-identifying parameters (Eizenberg 2011).

¹⁴This section is largely based on Ben-Shahar and White (2006) and reflects conversations with people in the industry.

¹⁵A fact that is important for the pass-through analysis in Hellerstein and Villas-Boas (2010)

¹⁶See Florida and Kenney (1991) for a discussion of how differences between Japanese and North American delivery requirements led to many North American owned suppliers not obtaining contracts to supply the initial Japanese “transplant” factories in North America.

¹⁷In the Elm International database of automotive supplier plants, which lists customers for given supplier plants, the vast majority of plants have more than one assembler customer.

multiple features of the industry. Over the past 30 years, just-in-time inventory control, where a part is delivered to the assembler soon before it is needed on the assembly line, has become a dominant logistics model (Klier and Rubenstein 2008). In this type of system, proximity to suppliers is important for flexibility and reliability of supply (KPMG 2005). Additionally, since many of these parts are bulky, the cost of shipping these products can be high. Furthermore, it may be that closer proximity leads to better quality control through lower monitoring costs.

3 Model

I model supplier firms' plant location decisions and assembler firms' procurement decisions (i.e., choice of supplier) using a two-stage game. Supplier firms first choose locations for their plants and then, after contract-specific shocks are realized, bid on contracts in a second-price auction (SPA).

3.1 Primitives

There are two types of firms in the model: upstream supplier firms, indexed by f , and downstream assembler firms, indexed by a . The number of suppliers and assemblers is fixed. Supplier firm f has the capabilities to produce parts, indexed by p , in the set \mathcal{P}_f . Conversely, the set of firms that make the part p is denoted \mathcal{F}_p . The set of parts that firms produce is taken as given.¹⁸

Firm f produces these parts in a set of plants \mathcal{I}_f , indexed by i . This set of plants has N_f elements, which is taken as given. Each plant i is located at a point (x_i, y_i) on the plane. In the first stage of the game, firms choose locations (x_i, y_i) for their plants i.e., firm f chooses locations for all of the plants in the set \mathcal{I}_f .

In the second stage, the upstream suppliers compete for contracts to produce parts for the downstream assemblers. The set of all contracts is denoted by \mathcal{R} . A contract r is a requirement to supply a quantity ψ_r of part $p(r)$ for model $m(r)$. These models are produced in different locations (i.e., assembler plants), which are taken as given.

The cost for plant i to supply one unit of part $p(r)$ to model $m(r)$ is given by:

$$C_{ri} \equiv \bar{C}_r + \bar{C}_{ri} + \epsilon_{ri} + \eta_{rf}$$

\bar{C}_r is the component of costs that is constant across all plants that produce the part, and

¹⁸The modeling of the part choice of supplier firms is certainly an important issue, but is one that this paper abstracts away from.

would generally include the costs of materials and the capital necessary to build this part. \bar{C}_{ri} varies by plant, and would generally include transportation costs, local labor costs, productivity differences, and relationship-specific human capital between the supplier and assembler. Both \bar{C} components are observed by all supplier firms and by the assembler.

There are two idiosyncratic components of supplier plant costs: ϵ_{ri} and η_{rf} . ϵ_{ri} is a contract/supplier *plant* specific cost. When assemblers award contracts to supplier firms, its realization is unobserved, but its distribution is known by the assembler and the other supplier firms. η_{rf} is a contract/supplier *firm* cost. This is unknown to all firms (supplier and assembler) when the firm is locating its plants, but is revealed to the firm before the auction stage.¹⁹ Examples of these costs include personal relationships and specialized skills at both the supplier plant and supplier firm levels.

3.2 Procurement

Consistent with profit maximizing behavior, supplier firms fulfill contract r in their lowest cost plant for that contract. However, when assembler firms choose a supplier for a given contract, the ϵ_{ri} 's have not yet been realized. Firm f 's expected per-unit cost to supply a given contract r (denoted C_{rf}) is given by:

$$C_{rf} \equiv \bar{C}_r + \underbrace{E_\epsilon[\min_{i \in \mathcal{I}_f}(\bar{C}_{ri} + \epsilon_{ri})]}_{\bar{C}_{rf}} + \eta_{rf}$$

I make assumptions on supplier firms' costs and assemblers' procurement mechanism.

Assumption 1. *Costs are additively separable across contracts.*

Assumption 2. *Contracts are awarded in a second-price auction.*

Assumption 3. *The set of contracts (\mathcal{R}) and the quantity needed for each contract (ψ_r) are taken as given (i.e., known in both periods and independent of costs).*

Assumption 1 implies that a supplier firm's costs to supply a given contract are unaffected by any other contract it obtains.²⁰ Assumption 2 provides a mapping from firms' costs to the

¹⁹Given the second-price auction mechanism (outlined below), I do not need to make any assumptions regarding whether η is private information or publicly known.

²⁰This assumption is bolstered by two facts about the industry. First, the capital needed to produce a part for a given model is frequently unique to that model and owned by the assembler (not the supplier). Second, within the WSW data (discussed below in section 4.3), in cases where multiple parts are listed for the same model within the same narrow part category (discussed below in section 4.3.1), in over 60% of cases these parts are supplied by different firms. That indicates that even within the same car model and narrow part group, many different firms are producing the parts. Both of these facts notwithstanding, without a formal model of complements it is not possible to know the precise extent of these complementarities.

winning firm for a given contract and its profits from the contract.²¹ Assumption 3 implies that the composition of a car and the quantity of cars produced is inelastic with respect to the price of parts for the car.²²

These three assumptions imply that a supplier firm obtains a contract r when it has the lowest cost of any supplier firm to produce part $p(r)$ for model $m(r)$:

$$C_{rf} \leq C_{rf'} \forall f' \in \mathcal{F}_{p(r)} \quad (1)$$

Its realized profits from this contract are

$$\pi_{rf} = \begin{cases} \psi_r(M_{rf} - C_{rf}) & \text{if } C_{rf} \leq C_{rf'} \forall f' \in \mathcal{F}_{p(r)} \\ 0 & \text{else} \end{cases} \quad (2)$$

where $M_{rf} = \min_{f' \in \mathcal{F}_{p(r)} \setminus \{f\}} \{C_{rf'}\}$. These are the standard profits from a second-price auction.

3.3 Supplier Firm Profits and Plant Location

Supplier firm profits consist of two components: expected variable profits and fixed costs. When supplier firms decide where to locate their plants, η_{rf} has not been realized for any of the contracts. Therefore, firms take expectations before maximizing their expected profits. These variable profits are dependent on the location of the firm's own plants and competitors' plants.

Conditional on plant locations, the expected profits of a supplier firm from contract r are

$$E_\eta[\pi_{rf}] = P_{rf} E_\eta[M_{rf} - C_{rf} | C_{rf} \leq C_{rf'} \forall f' \in \mathcal{F}_{p(r)}]. \quad (3)$$

This expression is the probability of firm f winning contract r times its expected profits if it does. Aggregating over all contracts, supplier firms' expected variable profits are given by

$$\tilde{\pi}_f \equiv E_\eta[\pi_f] = \sum_{r \in \mathcal{R}} E_\eta[\pi_{rf}] \mathbb{1}(p(r) \in \mathcal{P}_f) \quad (4)$$

where $\mathbb{1}$ is the indicator function.

²¹The use of second-price auction pricing (Bertrand pricing) to introduce imperfect competition into a model of product sourcing is used in Bernard et al. (2003) in the context of international trade.

²²Relaxing this assumption would require a model of how upstream costs pass-through into prices and automotive demand. Further, since there are many parts in a car, the demand elasticity with respect to most of them is likely to be small.

$\tilde{\pi}_f$, the expected profits of firm f , depends on the locations of its plants and its competitor's plants. Supplier firms locate their plants in order to maximize their profits, including fixed costs, which can vary by location. Therefore, they maximize

$$\max_{\mathbf{x}_f, \mathbf{y}_f} \tilde{\pi}_f(\mathbf{x}_f, \mathbf{y}_f; \mathbf{x}_{-f}, \mathbf{y}_{-f}) - \phi_f(\mathbf{x}_f, \mathbf{y}_f) \quad (5)$$

where $(\mathbf{x}_f, \mathbf{y}_f)$ are N_f dimensional vectors giving the locations of firm f 's plants and $(\mathbf{x}_{-f}, \mathbf{y}_{-f})$ are the locations of the plants of other firms. $\phi_f(\mathbf{x}_f, \mathbf{y}_f)$ is the fixed cost of locating firm f 's plants in the locations given by $(\mathbf{x}_f, \mathbf{y}_f)$.

3.4 Equilibrium

I use perfect Bayesian Nash equilibrium (PBNE) as the solution concept. Given plant locations and the realization of the η 's, supplier firms will bid to maximize their profits in each auction. Since the contracts are awarded using a SPA, in the unique equilibrium of each auction, firms will bid their true expected cost for supplying contracts. In the location stage, firms locate their plants to maximize expected profits (integrating over the η 's and ϵ 's) given the locations of other firms' plants. Firms have correct beliefs regarding the distribution of the η 's and ϵ 's.

This game could conceivably have many equilibria. Without the location stage, the auction stage is a standard SPA with a unique Bayesian Nash equilibrium. However, many different combinations of firms' actions in the location stage could be part of equilibrium strategies in the overall game. Therefore, I will use an equilibrium refinement in order to be able to use this model to simulate firm behavior.

Understanding the refinement that I use requires considering the firm location stage in isolation. Define a static game where firm payoffs are given by the firm ex-ante expected profits from the SPA (in equation (4)) and firms locate to maximize these ex-ante expected profits. I will refer to this game as the *static location game*. Any Nash equilibrium in the static location game has an associated PBNE in the full two-stage game. In these associated equilibria, the Nash equilibrium actions in the static game correspond to actions in the first stage of a PBNE strategy profile in the two-stage game.

Definition 1. A *cost-minimizing plant location* vector consists of locations for all supplier plants (\mathbf{x}, \mathbf{y}) such that

$$\sum_{r \in \mathcal{R}} N_r((\mathbf{x}, \mathbf{y})) + \sum_f \phi_f((\mathbf{x}, \mathbf{y})) \leq \sum_{r \in \mathcal{R}} N_r((\mathbf{x}, \mathbf{y})') + \sum_f \phi_f((\mathbf{x}, \mathbf{y})') \quad \forall (\mathbf{x}, \mathbf{y})' \quad (6)$$

where $N_r(\mathbf{x}, \mathbf{y}) \equiv \min_{f' \in \mathcal{F}_{p(r)}} \{C_{rf'}(\mathbf{x}_f, \mathbf{y}_f)\}$.

Definition 2. A *cost-minimizing Nash equilibrium* in the static location game is a Nash equilibrium where the equilibrium plant locations (\mathbf{x}, \mathbf{y}) are such that the inequality in equation (6) holds when $(\mathbf{x}, \mathbf{y})'$ are restricted to be the outcomes of a Nash equilibrium of the static location game.

I refine the set of PBNE by only considering PBNE where the location choices of firms in the first-stage are also the outcome of a cost-minimizing Nash equilibrium of the static location game. In the rest of this section, I show that a cost-minimizing plant location vector is also a cost-minimizing Nash equilibrium outcome (in the static location game). This makes it possible to solve for a cost-minimizing Nash equilibrium without searching for all possible equilibria, but instead minimizing a function.²³

Lemma 1.

$$E[\pi_{rf}] = E[M_{rf}] - E[N_r]$$

where $M_{rf} \equiv \min_{f' \in \mathcal{F}_{p(r)} \setminus \{f\}} \{C_{rf'}\}$ and $N_r \equiv \min_{f' \in \mathcal{F}_{p(r)}} \{C_{rf'}\}$.

This lemma states that the expected profits of firm f in market r are given by the difference between the expected minimum cost without firm f participating in the auction for contract r and the expected minimum cost with firm f participating in the auction for contract r . The proof is in appendix B.

Theorem 1. A vector of cost-minimizing plant locations is a cost-minimizing Nash equilibrium outcome of the static location game.²⁴

Proof. The cost-minimizing plant locations are the solution to:

$$\min_{\mathbf{x}, \mathbf{y}} \left(\sum_r E[N_r(\mathbf{x}, \mathbf{y})] + \sum_f \phi_f(\mathbf{x}, \mathbf{y}) \right)$$

which is equivalent to

$$\max_{\mathbf{x}, \mathbf{y}} - \left(\sum_r E[N_r(\mathbf{x}, \mathbf{y})] - \sum_f \phi_f(\mathbf{x}, \mathbf{y}) \right) \quad (7)$$

²³I show evidence in section 6 that this function has a unique minimum for the functional forms used in the location simulations.

²⁴This result is similar to Lederer and Hurter (1986), Arozamena and Cantillon (2004), and Jeitschko and Wolfstetter (2000). Lederer and Hurter analyze a two-stage location game with discriminatory pricing, but without uncertainty (which is included in this paper). Jeitschko and Wolfstetter as well as Arozamena and Cantillon analyze investment decisions before auctions. Both of these papers exploit the independence of costs and Jeitschko and Wolfstetter use continuity in their proof.

Also note that this result is also robust to modeling firm and plant entry and exit decisions. Therefore, with this SPA pricing structure, the efficient level of firm entry is a Nash equilibrium outcome.

In a Nash equilibrium of the static location game, firm f maximizes expected profit conditional on the behavior of the other firms. Rewriting equation (5) using lemma 1, I obtain:

$$\max_{\mathbf{x}_f, \mathbf{y}_f} \sum_r (E[M_{rf}(\mathbf{x}_{-f}, \mathbf{y}_{-f})] - E[N_r(\mathbf{x}_f, \mathbf{y}_f; \mathbf{x}_{-f}, \mathbf{y}_{-f})]) - \phi_f(\mathbf{x}, \mathbf{y})$$

Since $E[M_{rf}]$ does not depend on the location of firm f 's plants, the solution to this maximization is equivalent to the solution to

$$\max_{\mathbf{x}_f, \mathbf{y}_f} \sum_r (-E[N_r(\mathbf{x}_f, \mathbf{y}_f; \mathbf{x}_{-f}, \mathbf{y}_{-f})]) - \sum_f \phi_f(\mathbf{x}_f, \mathbf{y}_f) \quad (8)$$

The functions being optimized in display equations (7) and (8) are identical. Any solution to the maximization problem in equation (7) is also the solution to the maximization problem in equation (8), holding the locations of the other firms fixed. Therefore, the cost-minimizing plant locations are a Nash equilibrium. Since the cost-minimizing Nash equilibrium cost is bounded below by the overall cost-minimizing cost, the overall cost-minimizing plant locations are the cost-minimizing Nash equilibrium locations. \square

4 Data

In order to estimate the model above, I utilize data on supplier-assembler contracting, a panel dataset of supplier plant locations, and a panel dataset of the location of assembler production by model.

4.1 Assembler Data

From the Ward's Automotive Yearbook, I obtain production by car model by plant for all North American vehicles from 1990-2009.²⁵ Figure 1 shows the geographic distribution of automotive production by continent of assembler ownership for 1994 and 2007. This map shows the increase in production in the South driven by foreign-owned assemblers. This movement of production reinforces the motivation for this paper, to quantify the costs that determine supplier plant locations in the face of this change.

²⁵I manually geocoded the plants using the Elm International Database and the Toxics Release Inventory (TRI) of the Environmental Protection Agency.

4.2 Supplier Data

The panel dataset of supplier plants comes from the National Establishment Time Series (NETS), which is constructed by Walls and Associates using Dun and Bradstreet data. The version used in this paper contains data from 1990-2008, but only 1999-2008 will be relevant for the analysis. It is an establishment-level dataset containing employment, sales, corporate hierarchy, and location. Since this dataset includes establishments from all sectors of the economy, in order to obtain a dataset of large automotive supplier manufacturing plants, the data was winnowed using a process described in appendix A.1.

To supplement the NETS data, I manually include data on the supplier firms' continent of origin (Asia, Europe, or North America) and assembler firms with whom they have historical ties. When supplier and assembler firms are of the same continent of origin, I will refer to that as "continental endogamy" and when they have historical ties (i.e., formally vertically integrated or in the same keiretsu [industrial grouping]), I will refer to that as "historic endogamy." Additionally, as a control for other supplier-assembler relationship costs, I construct a variable measuring the percent of a supplier's business overseas (i.e., not in North America) that comes from a given assembler. This will be known as "global endogamy."

As a control for unobserved supplier quality, I include a German-quality measure, which is the percent of a supplier's business overseas that comes from the two German brands: BMW and Mercedes. From speaking with industry sources, luxury brands (which for BMW and Mercedes are large parts of their business) generally have higher quality standards for parts than non-luxury brands. Therefore, the ability of a supplier to obtain contracts from these luxury brands can be viewed as a measure of quality. The details of how these variables are constructed and how the datasets are merged is in appendix A.

Figure 2 shows the density of supplier plants by continent of origin in 2007. This map illustrates two major features of the geography of the industry. First, many supplier plants of all continents of origin are located in the Midwest in general and in the area surrounding Detroit in particular. This is true even for Asian-owned suppliers, even though no Asian assemblers have plants in Michigan. Second, the locations of suppliers of a given continent track, relative to other suppliers, the location of the assembler plants of that continent. For example, compared to European-owned and North American-owned suppliers, a larger share of Asian-owned supplier plants are clustered in the area due south from Detroit than other suppliers. This is also the location of many Asian-owned assembler plants.

As will be discussed in section 5, this paper uses data linking supplier *firms* to specific parts for specific models, but estimates plant level parameters. Therefore, it is important to ensure that there is sufficient variation in the geographic distribution of plants across firms in order to identify parameters related to plant location. Figure 3 shows the geographic

distribution of plants between firms by showing the geographic centroid of their plant locations. This figure shows that there is variation in plant location between firms, which is encouraging for the identification of location-specific parameters.

4.3 Vertical Contracting Data

These plant level data (both supplier and assembler) are merged to the “Who Supplies Whom” (WSW) dataset from Supplier Business.²⁶ This dataset is a list of supplier-model-part combinations. It is generated by contacting many of the largest suppliers to obtain a list of which parts the supplier firm is supplying to new models. A pseudo-sample of this dataset is in table 1.

The version of the WSW dataset used in this paper contains about 18,200 model-supplier-part combinations from models produced in North America. The data contain models from 1999 through 2009 with the largest coverage from 2004-2008.²⁷ The data for each model are typically entered in either the year the model was reintroduced or in the year of a major model adjustment. Only models produced in the United States and with unambiguous part categories are included in the estimation. This winnows the WSW database to about 13,500 observations. Of approximately 200 supplier firms in the merged NETS data, about 75% have at least one entry in the WSW database.

Figure 4 summarizes the WSW data by showing the importance of supplier/assembler relationships (endogamy) in determining contracts. Each assembler has a disproportionate (compared to the totals in the data) share of contracts from suppliers of their own continent of origin. This indicates that endogamy is important in determining which supplier firm obtains the contract. Furthermore, (as discussed in the previous section) supplier and assembler firms of the same continent of origin show similar geographic patterns.

These two patterns suggest that proximity to likely customers is important in this industry. However, it is not clear how to interpret the economics of these patterns. They could be generated by either low distance costs and high endogamy benefits or high distance costs and low endogamy benefits. The model in this paper will help to assess the relative impact of each of these factors on costs.

²⁶This dataset is also used by Fox (2011).

²⁷Thanks to Steven Wingett of Supplier Business for discussing the details of the dataset with me.

4.3.1 Parts

To estimate the model described above, data on which supplier firms make which parts is gleaned from the WSW, NETS, and the Elm International databases.²⁸ The WSW database contains a variety of different methods of categorizing parts, based on area of car (e.g., interior), broad system (e.g., body parts), and specific part (e.g., handles/latches). These were in turn manually categorized on the basis of the system and specific part into 153 part groups (this example would be in the latch/handle group, which would include handles and latches from all different systems of the car). Any firm in WSW, NETS, or Elm International (which is merged to the other data) that is listed as making a part within a given narrow part category in any of its plants is considered to have the capability of making that part. Note that within the WSW data, even within a narrow part category, there can be many parts for the same car (as in table 1, where brake brackets and brake pads are in the same narrow category), which are produced by different supplier firms.

Since transportation costs may differ by characteristics of the parts, such as the weight or the use of just-in-time inventory control for that part, parts are grouped in two different ways. The first grouping of parts captures parts that in my judgment are either heavier or more important in just-in-time sequencing. These parts are denoted as “big.” About 10% of all contracts listed in the WSW database are for big parts. The second grouping of parts uses data from the United States trade statistics to obtain a weight by value measure for each part. The expectation is that, independent of assembly line sequencing and the associated just-in-time concerns, parts that have a higher weight by value are more expensive to ship. The construction of this measure is described in appendix A.

4.4 Location Data

Each place where a plant is located is characterized using a vector of characteristics reflecting local labor market conditions, historical industry agglomeration, and the driving distance to each assembler plant. This section describes these variables and more details are included in section A.

The local labor market conditions are measured in three ways: status of a state as right-to-work, state unionization rates, and local wages. Similar to Holmes (1998), states are grouped into right-to-work (RTW) law states and non right-to-work law states (NRTW).²⁹ In a RTW state, the legal regime bans workplaces where employees are required to join a

²⁸The Elm International Database is a database of automotive supplier plants. It includes their location, employees, assembler firms supplied, and parts made at a given point in time. The version used this paper is from 2008.

²⁹Obtained from <http://www.dol.gov/whd/state/righttowork.htm>

union (Holmes 1998). Holmes also uses this law as a proxy for a larger industrial climate as “pro-union” or “pro-business.”

A very similar measure to this is the state unionization rate. I construct this by computing the probability of an individual in a given state and year joining a union, controlling for the differing rates of unionization in different industries and in different years. The details of the construction of this variable are in appendix A. Maps of the two state unionization variables for 2007 are in figure 5 and figure 6. The state unionization rate variable, which controls for year effects, allows for the general decline in unionization to be reflected in the data, and for more variation between states. However, in general, the patterns stemming from each of these variables are very similar.

The local wage rate in each location is constructed by smoothing the manufacturing wages obtained from County Business Patterns. The details of how this variable is constructed are included in appendix A. This variable is meant to control for the different labor market conditions in local labor markets, conditional on the broader state policies. Note that since equilibrium differences in wages could both stem from higher labor productivity or other labor demand/supply shifters, this variable will not be interpreted in a causal manner.

In addition to these labor market variables, I also consider that locations may differ in their desirability to suppliers, for reasons related to the presence of other suppliers. This may include classical agglomeration rationales of information sharing or labor market pooling (see Duranton and Puga 2004). This is included in two ways – the crow flies distance from a given location to Detroit (the historical industry center) and the concentration of other supplier plants in a given area.³⁰ Furthermore, since most large suppliers maintain a research office in the Detroit region, the distance from Detroit also reflects the potential benefits associated with a plant’s proximity to the research hub of the industry.

Finally, locations differ due to the benefits of proximity to different assemblers. This could result either from shipping costs, just-in-time logistics costs, or monitoring costs. For a given car model, the Ward’s Automotive Database gives the assembler plant(s) where that model is produced. The distance from a given supplier plant to a given assembler plant is computed in two ways: driving time and crow-flies distance.³¹ In cases where an assembler produces a model in more than one plant, I assume that the distance costs are proportional to the share of production of that model in each plant.³²

³⁰This is elaborated upon in appendix A.

³¹I measure driving time using the Network Toolbox in ArcGIS.

³²While some shipping in this industry is via rail, the driving network is a reasonable proxy for the costs of distance in those cases as well.

5 Variable Cost Estimation

In section 5.1, I discuss the estimation of variable costs using the procurement portion of the model presented in section 3. Then, I present the results of the variable cost estimation in section 5.2. Discussing the simulation of equilibrium supplier plant locations using the location portion of the model is deferred until section 6.

5.1 Estimation

The empirical implication of the assembler procurement portion of the model is that the low-cost supplier firm for a given part obtains the contract to produce it. The probability of firm f being the low-cost firm for contract r is:

$$P_{trf} = Pr(\bar{C}_{trf} + \eta_{trf} < \bar{C}_{trf'} + \eta_{trf'} \forall f' \neq f \in \mathcal{F}_{pt}) \quad (9)$$

where η is unobserved to the econometrician.³³ I assume that $-\eta_{trf}$ is distributed independent type-I extreme value (“logit”) across markets and firms. Therefore, the probability of firm f winning contract r takes the familiar logit form:

$$P_{trf} = \frac{\exp(-\bar{C}_{trf})}{\sum_{f' \in \mathcal{F}_{p(r)t}} \exp(-\bar{C}_{trf'})}$$

For the estimation, I assume that $-\epsilon_{tri}$ is distributed type-I extreme value.³⁴ Therefore, using results from McFadden (1978),

$$\bar{C}_{trf} = -\lambda \log\left(\sum_{i \in \mathcal{I}_{tf}} \exp\left(\frac{-\bar{C}_{tri}}{\lambda}\right)\right). \quad (10)$$

I parametrize \bar{C}_{tri} using a linear specification, such that

$$\bar{C}_{tri} = \beta_p^d \tau(d_{mi}) + \beta_i^u u_{ti} + \gamma X_{tri}. \quad (11)$$

d_{mi} is the distance between the supplier plant and the assembler plant where model m is produced. Note that β_p^d is indexed by p , in order to allow for different parts to have different benefits of proximity. Specifically, this parameter is allowed to vary by the part groupings

³³Since I pool data from many years in the estimation, I include a t subscript in this section.

³⁴The variance of $-\epsilon_{tri}$ is $\lambda^2 \frac{\pi^2}{6}$, where $\frac{\pi^2}{6}$ is the variance of the standard type-I extreme value distribution. These distributions for ϵ_{tri} and η_{trf} are equivalent in terms of the estimation to a nested logit specification where λ is the nesting parameter.

described in section 4.3.1. Distance is measured in two primary ways: driving time (in hours) along the road network and crow flies distance. The way in which distance interacts with costs is measured using linear and quadratic specifications of the τ function.

u_{ti} is a measure of state labor market policies in the state where plant i is located in year t . It is either a dummy variable for whether a state is right-to-work or the state’s predicted unionization rate as described in section 4. Note that β_i^u is indexed by i , in order to allow for different firms to have different sensitivities to state labor market policies. Specifically, this parameter is allowed to vary by the whether the supplier firm is of North American or foreign origin. For the plant location simulations, u_{ti} will be the estimated “unionization gradient” at the location of plant i . The details of the construction of this gradient are in appendix A.10.

X_{tri} includes covariates for supplier firm continent of origin, supplier/assembler match characteristics (e.g., the historical endogamy variable), and location-specific characteristics (e.g., supplier firm concentration, local wages). The supplier continent of origin variables are primarily included to improve the power of the parameter estimates of primary interest. The location-specific characteristics such as local wages, geographic supplier firm concentration, and distance from the industry center in Detroit are included to control for other characteristics of locations and isolate the impact of the main parameters of interest.

Supplier/assembler match characteristics are included in the X_{tri} both because they are of independent interest and because they are important for understanding plant location. The model presented in section 3 with the functional form in this section implies that the covariates in the cost function are complements in profits. Therefore, if costs are lower to supply some assemblers due to these match-specific costs, then a supplier will want to decrease their distance to that assembler’s factories.

Finally, it is important to define the “outside option,” which is reflected in the continent of assembler-specific constant term in the estimation. This is when a supplier that is not in the top 150 Automotive News suppliers in any of the years listed above or a supplier that has no U.S. plants obtains the contract to produce a given part for a given car. In order to control for any changes in the value of the outside option over the sample period, a linear time trend is included.³⁵

All of these covariates (d_{mi}, u_{ti}, X_{tri}) are assumed to be independent of ϵ_{tri} and η_{trf} . Further, the model assumptions imply the conditional independence of the P_{trf} from each

³⁵These changes include the increase in imported parts and the efforts by automotive suppliers to award contracts to a smaller number of suppliers over this period.

other. Therefore, the likelihood to estimate variable costs is given by

$$\mathcal{L}(x; \alpha, \beta, \gamma) = \prod_t \prod_r \prod_f P_{trf}(x; \alpha, \beta, \gamma) \quad (12)$$

While the probabilities in the data are at the firm level, some of the cost parameters are at the plant level, with identification coming from variation in the distribution of plants between firms.³⁶

5.2 Results

I first preview the results presented in this section before discussing the specifics. Confirming economic intuition, a plant located in a high unionization rate/non-RTW state has higher costs (and is less likely to obtain contracts), while a plant located closer to the factory where a model is being produced has lower costs for supplying that model (and is more likely to obtain the contract). The impact of the state unionization rate/RTW status also differs by the continent of origin of the supplier firm, which is consistent with the costs associated with state labor market policies being mediated by other political factors. These main findings are robust to a series of different specifications.

Table 2 shows the results from maximizing the likelihood in equation (12). This table contains results from five different parameterizations of \bar{C}_{tri} , with the basic structure as is shown in equation (11). All specifications include: dummy variables for the continent of the supplier and the assembler, a linear year trend, continental endogamy dummy variables (e.g., North American Supplier X North American Assembler) and historical endogamy dummy variables. The “base” specification includes the (crow-flies) distance to Detroit. The “wage” specification includes distance to Detroit and the local wage. The “global” specification includes distance to Detroit, the global endogamy measure, and the German-quality measure. The “agglom” specification includes the local concentration of supplier plants. Finally, the “wgt” specification includes distance to Detroit and replaces the “big” part measure with a part’s weight by value. More details on the construction of these covariates is in section 4.

The coefficients on the distance variables indicate that costs (\bar{C}_{tri}) are increasing in geographic distance. It follows that plants that are geographically closer to the assembler plant where a car model is being produced are more likely to obtain the contract to supply that model than plants that are geographically farther away. While in many ways this is an intuitive result, to the author’s knowledge this is the first paper to estimate the costs of

³⁶The assumption in this paper is that supplier firms are producing from one of their plants in the U.S., while it could be that the supplier is importing from one of its foreign plants.

distance in upstream-downstream sourcing.

There is also suggestive evidence that literal transportation costs (e.g., trucking, rail) is at least part of the reason for the benefit of proximity. In markets for parts classified as “big” (which are either larger or typically supplied just-in-time) and for parts with a higher weight to value ratio, the benefits of proximity are much greater. Further disentangling the different benefits of proximity (e.g., transportation costs, monitoring, information sharing) is left for future research.

The state labor market policy variables (state unionization rate or right-to-work status) indicate that assemblers are more likely to choose suppliers in states with less union “friendly” policies, controlling for the other covariates.³⁷ Interestingly, this impact is much less, if not completely eliminated, for the North American owned supplier firms. This is consistent with the impact of state labor market policies being mediated through broader relationships between the unions and the supplier and assembler firms. Based on historical factors, North American owned suppliers and assembler firms are more likely to have positive relationships with the unions, so regardless of plant location the union is more likely to be welcomed in the plant. Further, union contracts are frequently done on a firm-wide basis, so the location of any particular plant in the firm would be irrelevant to the union’s impact in the plant. However, when in a less “union friendly” environment, the foreign suppliers are more likely to be able to avoid a relationship with the unions.³⁸

It is important to emphasize that the impact of unions on firms in this industry goes beyond wages. In particular, unions can impact costs through workplace rules that precisely define workplace tasks. This rules-based approach can make it more difficult for the management in the plant to change procedures or tasks in response to changing market conditions.³⁹ The “wage” specification for variable costs provides suggestive evidence supporting this point. In this specification, even conditional on the local wage, foreign-owned suppliers have lower costs when locating in a right-to-work state.

With these findings, I corroborate previous work on the impact of state labor market policies on firms (e.g., Holmes 1998), but do so using vertical contracting data. Using this type of data to address these questions is new. Furthermore, since the data used in this paper contain information on the parent companies of firms, this paper can identify the heterogeneous impact of these state labor market policies.

As described in the previous section, a number of characteristics of suppliers and of

³⁷Results for the state unionization rate appear in the next section.

³⁸“Unions and companies agree that foreign-owned plants do not provide an environment conducive for collective bargaining” (Klier and Rubenstein 2008)

³⁹In conversations with some people in the industry, they cite this as the major cost associated with a union in the factory.

a supplier/assembler match (endogamy effects) are included in order to help to control for unobserved costs. When the supplier and assembler firms are of the same continent of origin, have “historical ties” (historic endogamy), or have a stronger global working relationship (global endogamy), the variable costs associated with contracts between those firms are lower. It is more likely for supplier firms of one continent of origin to supply an assembler of the same continent of origin, possibly due to tighter historical working relationships between the two or a similar workplace culture making it easier for them to work together.⁴⁰

The linear specification for distance provides a natural metric with which to compare the magnitudes of these coefficients.⁴¹ In figure 7, I compare the components of variable costs by plotting a cost-equivalent for each coefficient in terms of miles proximity to a given assembler. For example, for a foreign-owned supplier firm, having a plant in a right-to-work state decreases costs by an amount equivalent to having a plant 2,300 miles closer to a given assembler.⁴² In contrast, for a domestic-owned supplier firm, having a plant in a right-to-work state is equivalent to having a plant only 200 miles closer to a given assembler. The endogamy impacts vary widely, ranging from 1,200 miles for North American owned suppliers and assemblers to nearly ten times that for Asian suppliers and assemblers. The historic and European endogamy effects are in the middle at approximately 6,000 miles cost-equivalent.

6 Plant Location Simulation

6.1 Simulation Procedure

The empirical implications of the plant location portion of the model are in equation (5). Using the distributions for ϵ and η described in the previous section and results from lemma 1, the expected profits for firm f in market r are given by:

$$E[\pi_{rf}] = \log\left(\sum_{f' \in \mathcal{F}_{p(r)}} \exp(-\bar{C}_{rf'})\right) - \log\left(\sum_{f' \in \mathcal{F}_{p(r)}/f} \exp(-\bar{C}_{rf'})\right) \quad (13)$$

In words, this is the “logit inclusive value” of all firms’ costs for market r minus the “logit

⁴⁰For example, referring to the initial Japanese transplant assemblers, Florida and Kenney (1991) note: “Unfamiliar with the just-in-time system and deeming Japanese quality demands unreasonable, many U.S. part suppliers simply chose not to sell to the transplants.” The affinity between companies of the same country of origin was confirmed through conversations with industry sources. Also see the discussion in section 2.

⁴¹These results are from the “global” specification and use a “non-big” part as a point of comparison. I convert driving time to miles using an average speed of 60 miles per hour.

⁴²Clearly, one should not take these too literally since some are extrapolations of distance beyond the size of the continental U.S., but they do give a sense of magnitudes.

inclusive value” of all firms’ costs excluding firm f ’s costs.

Due to the limitations of the dataset described in section 4, the likelihood in section 5.1 is estimated using only using a subset of U.S. automotive parts contracts. However in order to compute a measure of *total* profits for supplier firms, it is necessary to have a measure of the complete set of contracts being offered in cars. Approximating the set of contracts has two components: the set of cars with contracts up for bid and the set of parts in each car. The set of cars with contracts up for bid is taken to be the full set of cars produced in the United States in 2007 (d_m), which is taken from the Ward’s Automotive Database. While as described in section 2, car models typically only undergo major revisions and solicit bids for parts once approximately every five years, given the data it is not possible to know which cars have contracts up for bid in any given year.⁴³ Furthermore, since it is not possible to know the exact set of outsourced parts for all cars, this paper assumes that a given part in a given car is put up for bid with a probability given by that part’s share of total contracts in the WSW database (s_p). Therefore, the demand for a given contract is $\psi_r = s_{p(r)} * d_{m(r)}$.

As discussed in section 3.4, the cost-minimizing Nash equilibrium locations can be computed by solving for the cost-minimizing plant locations in the static location game (defined in section 3.4). These locations are given by solving

$$\min_{\mathbf{x}, \mathbf{y}} \sum_{r \in \mathcal{R}} E[N_r(\mathbf{x}, \mathbf{y})] + \sum_f \phi_f(\mathbf{x}_f, \mathbf{y}_f). \quad (14)$$

The equilibrium vectors of plant locations ($\mathbf{x}^*, \mathbf{y}^*$) are the solution to this optimization problem.

I do not specify a functional form for ϕ , the fixed costs. I will not estimate the distribution of these costs nor will I conduct simulations including them. Given the static model used to model firm locations, it is not possible to distinguish between location-specific costs for opening plants (e.g., zoning, infrastructure) and the history dependence of plant locations through fixed and sunk costs. Therefore, I conduct simulations of plant location that do not require distinguishing between these two types of fixed costs.

6.2 Results

In this section, I assess the relative magnitude of fixed, distance, and labor costs in determining supplier plant location. I compare the equilibrium supplier locations if firms located their plants solely on the basis of variable costs to the actual plant locations in 2007. I

⁴³While one could assume that with a given probability a model is undergoing a major revision, this would simply enter the calculation of profits as a scaling factor. Since profits are only estimated up to a scaling parameter anyway, this would not change anything in the computations.

also model plant locations if firms their plants located solely on the basis of labor costs or solely on the basis of variable costs. These simulations suggest that the major factor pushing suppliers towards the South is labor costs and not fixed or distance costs.

In order to conduct these simulations, I minimize the function in equation (14) setting $\phi_f(x, y)$ equal to a constant. I make three changes to the cost function in the previous section in order to make this minimization computationally tractable. First, I use a quadratic distance cost function using crow-flies distance instead of the linear function using driving distance from the previous section. Second, I use a quadratic function for the costs of locating away from the Detroit industry center. Third, I use a second-order spline in order to estimate a unionization “gradient” instead of using the binary right to work measure. Using this continuous (in x, y coordinates) measure of unionization and distance enables me to use a gradient method to minimize the planner’s cost function.⁴⁴ Details of the computation of this unionization measure are in appendix section A.10. Using the strictly convex quadratic cost function for unionization and distance makes finding a minimum computationally easier and makes it more likely that the function has a unique minimum. In practice, the function seems to have a unique minimum.⁴⁵

In the simulations, I focus on the part of the U.S. where most of the automotive production takes place and most of the suppliers are located.⁴⁶ Therefore, I restrict the choice set for suppliers to be a rectangle surrounding that region and fix the locations of the suppliers located outside of that region.⁴⁷

Table 3 shows the results from the modified variable cost function. I show both the results using a linear and quadratic specification for costs.⁴⁸ These cost estimates are qualitatively similar to the variable cost estimates from the previous section.

Figure 8 shows the mean of the simulated equilibrium plant locations and actual plant locations (in 2007) by continent of origin. Overall, if firms only locate on the basis of variable costs, the mean center of the industry would be located 290 miles south of its actual location in 2007.⁴⁹ This difference is much larger for the foreign-owned supplier plants than

⁴⁴In the variable cost estimation, I use the state’s predicted unionization rate as described in section 4.4, but in computing optimal locations I use the spline approximation to the unionization rate.

⁴⁵I used a multi-start algorithm (10 alternative starting points) in KNITRO to solve the maximization problem. This minimum of this minimization from the multi-start algorithm was nearly identical to the solution from solving the problem starting at the observed data points in 2007 (the mean of plant locations within each group were within 5 miles of each other).

⁴⁶In 2007 86% of suppliers were in this part of the country.

⁴⁷In particular, I use the U.S. National Atlas Equal Area Projection (SRID 2163) to define the x, y coordinates. I use a rectangle (in the transformed projection) bounded by $(-96.9, 29.2)$, $(-74.8, 43.1)$, $(-99.6, 45.9)$, and $(-98.0, 29.2)$.

⁴⁸All calculations in the rest of the section are using the “trans2” specification.

⁴⁹Since the coefficient on unionization for North American owned suppliers is not statistically significant from zero, I ran a simulation with that coefficient set equal to zero. Under this robustness check, the mean

the domestic-owned ones. For Asian supplier plants, the equilibrium mean center in the simulation would be 400 miles farther south than its actual location.

This exercise shows where the industry would locate if suppliers located solely on the basis of variable profits. Since the industry is farther north than the model of variable profits predicts, that suggests that fixed and sunk costs play an important role in determining supplier plant location. Due to existing capital investments, it can be costly for a firm to close a plant in one location and open one in another. Therefore, plants may remain in the Midwest even if from a variable cost perspective they should move to the South. Further, the infrastructure and regulatory approval to open a plant is likely to be in place in the Midwest due to the region's history as an industry center. In particular, that region has the necessary infrastructure (i.e., roads, rail lines), zoning (i.e., environmental regulations), and buildings (i.e., physical plant) to support automotive suppliers. Therefore, the location-specific fixed costs of opening a plant in the Midwest should be lower than elsewhere. For any given contract, the costs of operating in the South may be lower (particularly for the foreign-owned suppliers). However, in many cases these advantages may be reduced by the costs associated with obtaining (and maintaining) the necessary ecosystem for their plant.⁵⁰

Figure 9 shows the equilibrium mean locations of supplier plants if firms located plants solely on the basis of labor costs or solely on the basis of distance costs. To model firms locating solely on the basis of labor costs, I set distance costs (and fixed costs) equal to zero. To model firms solely locating on the basis of distance costs, I set a uniform national unionization rate of 4%. This is the rate in North Carolina, the lowest rate of any state.⁵¹ This map shows that the mean equilibrium plant location is in the South when firms locate solely based on labor costs and is in the Midwest when firms locate solely on the basis of distance costs.

Combining the information from these three simulations, the main factor pushing suppliers to the South is the lower labor costs there. As discussed above, based on comparing the actual plant locations with the simulated "variable cost only" plant locations, fixed costs help to push the industry towards the Midwest. With the 2007 distribution of assembler production (with 18% in the South), the Midwest is the optimal location for supplier plants locating solely on the basis of distance costs. However, supplier plants that locate solely on the basis of labor costs would locate in the South.

Figure 10 shows how the movement of downstream assembler production would impact (Asian and North American) suppliers locating solely on the basis of distance costs. I simu-

center of the industry would be located approximately 110 miles south of its location in 2007.

⁵⁰See Canup (2007) for more information of how this type of cost influences supplier site selection.

⁵¹I include the costs of locating away from Detroit in both specifications.

late suppliers' equilibrium plant locations as the share of production in the South changes.⁵² While the mean center of supplier plant locations moves South with assembler production, comparing North American and Asian firms' behavior is revealing. Since much of the automotive production in the South is from Asian owned assemblers, the Asian firms move south at much lower levels of southern production than the North American owned firms. While the North American owned firms do eventually move south, it is only at much higher levels of production in the South that their move south accelerates.

This simulation illustrates how different types of firms respond differently to the same changes in the economic environment. These differences in firm behavior have welfare consequences. I show one example of these consequences by showing how supplier firms with different continents of origin respond differently to unionization. As discussed above, these responses are consistent with workers in these plants having different working conditions and wages. Furthermore, since these supplier firms have different likely downstream customers, they will respond differently to changes in downstream competition. These responses will also, in turn, have differential impacts on the local economies where these plants locate. Therefore, it is important to not just consider the overall number of firms locating in a region, but also the type of firms.

7 Counterfactual Exercises

I conduct two counterfactual exercises simulating a reduction in the impact of unions on costs in this industry.⁵³ First, I simulate the impact of reducing the power of unions in states in the Midwest. This counterfactual is motivated by the politicians in that region who are currently trying to pass right-to-work laws or other laws less favorable to unions.⁵⁴ Second, I simulate the impact of a reduced labor cost premium at domestic-owned supplier plants. In recent negotiations between the United Auto Workers (UAW) and the domestic-owned assemblers, the unions made significant wage concessions. According to some, these yielded parity with the wages at the foreign-owned assemblers (McAlinden 2011). I simulate the impact of a similar parity at supplier plants in the industry.

For both of these counterfactuals, I consider the impact of this cost reduction on the overall expected cost of producing parts.⁵⁵ To serve as a point of comparison, I compare

⁵²With each plant within the region maintaining its within-region share of production.

⁵³For these counterfactuals, I use the same specification for variable costs as in the previous section.

⁵⁴As of this writing, Indiana had succeeded in passing "right-to-work" legislation. It is important to note that a state's right-to-work status is frequently associated with a range of other policies related to business climate. These counterfactual exercises do not attempt to isolate the impact of any given piece of legislation, but represent the overall affect of adjusting the business climate in the state.

⁵⁵This is the expected cost of production, not the expected costs to the assembler (i.e., this number does

the change in the expected assembler costs resulting from these labor market changes to the change in the expected assembler costs resulting from the elimination of all distance costs.

For the first counterfactual, I simulate the impact of every state having uniform costs associated with unions at a level equal to the union-associated costs in the lowest-cost state. In this counterfactual, I maintain the different responses by foreign-owned and domestic-owned suppliers to the state labor market environment. The assumption is that, at least in the short run, changes in state policy would not undo the impact of the deeply rooted relationships between the suppliers and unions. I show the results from this counterfactual experiment in table 4 and summarize the results by aggregating the results by region and assembler continent of origin. The reduction in the costs of unions has the greatest impact on the cost of parts for assembler plants in the Midwest and for foreign assemblers. For the whole industry, the reduction in costs is equivalent to approximately three times the cost savings from eliminating all distance costs.

There is a particularly large reduction in labor costs for assemblers in the Midwest, the region where there is the largest reduction in the costs associated with unions. The assembler plants located closest to this cluster of suppliers benefit most from these suppliers' lower labor costs. Foreign assemblers benefit more than domestic assemblers from these reduced labor costs, since Asian and European suppliers (who are likely to supply them) reap the largest benefits from this reduction in the unionization rate. In contrast, the suppliers to the North American owned assemblers are likely to be North American, who are less sensitive to changes in unionization rates (likely because of their national union relationships).⁵⁶ This example illustrates a broader point. The impact of changes in supplier variable costs on assemblers are mediated by the geographic distribution of supplier firms and supplier/assembler relationships.

Since this counterfactual fixes the locations of suppliers, the long-run benefits to the assembler firms in the Midwest are likely understated while the benefits to those in the South are likely overstated. Over time, supplier plant locations would change in response to this shift in labor costs, and many of the suppliers that previously located in the South would move further north. As the South becomes less attractive relative to the Midwest, more plants would open in the Midwest to be closer to the large center of automotive production. This shift of plants towards the North would, over time, further decrease the costs for the assemblers in the Midwest and dampen the benefit for the firms located in the South.

For the second counterfactual, I simulate the impact of labor-cost parity between the

not include markups).

⁵⁶For this counterfactual I assume that their overall sensitivity to the state unionization rate would remain unchanged for both North American and foreign-owned suppliers.

domestic-owned and foreign-owned suppliers. I assume that the labor costs of foreign-owned suppliers in Michigan are equal to those of the domestic-owned suppliers in that state. The intuition for this assumption is that in locations with a high union prevalence, the foreign-owned firms still need to achieve near parity with the (likely unionized) domestic firms in order to hire workers. I make this assumption to recover the level of the labor cost gap between foreign-owned and domestic firms, since I do not directly observe the level of labor costs.

In order to recover the labor cost gap, I decompose the labor costs of a firm into two parts, the overall level and the part that depends on the unionization rate.

$$l_d(u) = \alpha_d + \beta_d u$$

$$l_f(u) = \alpha_f + \beta_f u$$

where $l_c(u)$ is the labor cost of a firm from continent c (d is domestic and f is foreign) in a location with unionization rate u . From the estimation of variable costs, I have estimates of β_d, β_f . By assuming that $l_d(u_m) = l_f(u_m)$, where u_m is the Michigan unionization rate, I can recover $\alpha_d - \alpha_f = u_m(\beta_f - \beta_d)$. Eliminating the labor cost gap in this model means setting $\alpha_d = \alpha_f$.

The change in assembler costs from instituting this labor cost parity are in table 5. For the whole industry, the reduction in costs is eight times the reduction that would come from eliminating distance costs. The impact of this labor cost parity is the highest on the North American owned assemblers, since their likely suppliers are the domestic-owned supplier plants.

8 Conclusions

The last 20 years has been a time of transition in the U.S. automotive industry. During this time, foreign-owned assemblers have increased production of cars in the U.S. by opening plants in lower labor cost Southern states. This move away from the traditional industry center in Detroit has even led some to wonder whether this reflects a broader shift in the importance of agglomeration in the economy as a whole (Krugman 2009). In light of these changes, it remains to be seen whether the deeply rooted industry agglomeration in the Midwest will move, remain largely intact, or break up.

In this paper, I study the location decisions of upstream automotive suppliers. Overall, these automotive suppliers employ hundreds of thousands of workers in their plants, more than are employed by the assemblers in theirs (Klier and Rubenstein 2008). Therefore, the

future path of the industry will be greatly impacted by where these firms locate plants.

I show the relative importance of three key factors driving where large automotive supplier firms locate their plants: fixed costs, labor costs, and distance costs. Broadly, I find that fixed costs orient the industry towards the Midwest, while labor costs orient the industry towards the South. Using my model of supplier plant location, I find that if fixed costs did not impact plant location, the mean center of the industry would be 290 miles farther south of its location in 2007.⁵⁷ Further, if supplier plants located solely on the basis of distance costs, the industry center would be in the Midwest (given 2007 production). Therefore, in 2007, labor costs were the major factor pushing suppliers south. However, if automotive production continues moving south, distance costs will be less and less of a factor keeping plants in the Midwest.

I also show how labor costs and distance costs differentially impact the plant locations of domestic-owned and foreign-owned automotive suppliers. From a labor cost perspective, having a plant in the South is more beneficial for a foreign-owned supplier than for a domestic-owned supplier. For a foreign-owned supplier firm, having a plant in a right-to-work state is cost-equivalent to having a plant 2,300 miles closer to a given assembler. However, for domestic-owned supplier firms, it is cost-equivalent to having a plant only 200 miles closer. Further, firm-specific relationships mediate the impact of distance costs on plant location, driving suppliers to locate plants closer to their likely customers. I estimate the impact of endogamy between supplier and assembler firms (firm-specific relationships). For Asian suppliers supplying Asian assemblers, this impact is cost-equivalent to having a plant 10,000 miles closer to an assembler, while for firms that have historic ties it is cost-equivalent to having a plant 6,000 miles closer.

The issues I address in this paper are relevant well beyond the automotive industry, since there are many other industries in which a firm's decision of where to locate a plant depends on other plants' locations (frequently due to distance costs).⁵⁸ With the establishment of many new industrial clusters in China, understanding the factors driving these clusters is becoming increasingly important. As China continues to industrialize and wages there increase, it is an open question whether these industrial clusters will move to lower cost countries, break up, or remain in China.⁵⁹ Which path a given cluster will follow is likely to depend on the relative magnitudes of the firms' labor, distance, and fixed costs. Better

⁵⁷See section 6.2 for a discussion of some of the ways in which fixed costs can drive plant location.

⁵⁸A recent New York Times article (Duhigg and Bradsher 2012) quotes an executive from Apple highlighting the importance of this proximity in the manufacturing of iPhones: "You need a thousand rubber gaskets? That's the factory next door. You need a million screws? That factory is a block away. You need that screw made a little bit different? It will take three hours."

⁵⁹See The Economist (2012a) for a recent article addressing this issue.

understanding these costs in a range of industries is therefore an important area for future research.

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A Data Appendix

A.1 Winnowing NETS Data

This section describes how the NETS data was processed.

First, I manually evaluated the detailed industry coding used in the NETS database, and selected codes that were related to the automotive supplier industry.⁶⁰ These industry codes are assigned on a yearly basis and any plant that contains a relevant industry code in any year is included in the dataset. This yields approximately 56,000 plant locations (spanning all years).

A second level of winnowing is performed to include only plants that belong to firms that are likely to be primarily supplying assemblers. I construct a list of this set of firms by using the list of the top 150 automotive suppliers by North American revenue that is constructed on an annual basis (since 1994) by Automotive News.⁶¹ I use the union of the set of firms on the list from 1999-2008 (and 1994), which yields approximately 280 firms. Of these firms, 228 were able to be matched to the NETS data.⁶²

Finally, in order to attempt to ensure that only manufacturing plants and not warehouses or sales offices are included in the analysis, establishments are only included in the dataset if they have more than 50 employees. The assumption is that sales offices and warehouses, and not manufacturing plants, would be the establishments with a small number of employees.⁶³ This reduces the number of plant locations (from 1999-2008) to approximately 2.7 thousand and the number of firms to approximately 200.

A.2 Matching Firms

I attempt to match all firms in the Automotive News “Top 150 North American Automotive Suppliers” from 1994 and 1999-2008 to three datasets: NETS, WSW, and the Elm International Database. I match firms to the NETS database using a manual match on the name of the headquarters, “trade name” of the headquarters, name of plant, and “trade name” of the plant. If the name in any of those fields (or crucial part of the name) matches the name, I manually inspect the result list. If the firm matches the headquarters name, it is considered a match. If it matches the “trade name” of the headquarters, and there is nothing in the

⁶⁰This is a “nine digit” SIC coding scheme and is therefore more detailed than the standard SIC coding scheme. A list of these codes can be obtained from the author upon request.

⁶¹Note that these firms could have parent companies from any continent – Asia, Europe, or North America.

⁶²One reason why firms may not match is that they have no plants in the United States and either have plants in Canada or Mexico and/or supply the North American industry from plants abroad.

⁶³In the Elm International Database (described in footnote 28), only 10% of automotive supplier manufacturing plants are listed as having less than 50 employees.

headquarters name that conflicts with it, that is considered a match. If a company name or company trade name matches, the headquarters code is inspected to see what other plants are in that firm and a determination is made whether or not to include it.

The match to WSW and Elm is made on the basis of a manual text search on the names for the firm in each of the databases.

A.3 Parts

The baseline categories are constructed as described in the main text from the WSW dataset. In addition to these categories, the WSW dataset contains the part name “as reported by the supplier.” These part names are more specific than the general categories, and these supplier reported part names are used as guides in the merges that follow.

The baseline categories described above are manually matched to the 9-digit SIC codes in the NETS data.

The Elm International dataset contains a listing of parts made in each supplier plant. Using the supplier reported part names from WSW as guides, these are merged to the baseline categories above.

Finally, parts are merged to the HS codes from the United States import data (downloaded from <http://www.som.yale.edu/faculty/pks4/sub-international.htm> and <http://cid.econ.ucdavis.edu/>). I match the HS codes in the trade data to the main categories that I delineated. An HS code is assigned to a main category if it matches a SIC code from at least one plant that is from a firm that is classified as making that part. If there is no match within that set, then I search over all HS codes and try to find a match. This match was also done manually using the “supplier reported” part names from WSW and the commodity description from the HS dictionary as guides.

A.4 Firm Continent and Tying

I constructed variables for firms’ continent of origin and historical ties using internet research and Klier and Rubenstein (2008). The continent of origin was determined on the basis of the parent company’s country of origin.

The “historic endogamy” variable differs by the continent of the supplier. For North American owned firms, this variable is for suppliers and assemblers that were formally vertically integrated. For Japanese firms, this is for firms that are in the same keiretsu (or in the case of Honda, a listed affiliate)

A.5 Global Ties/German-Quality

The “global-ties” measure is constructed using the world version of the WSW dataset from Supplier Business. For every supplier, I compute the percentage of part-model combinations in the dataset from a given supplier that are with a given assembler. This is their “global tie.” For example, if 70% of Denso contracts listed in the dataset are to Honda, then this variable would be .7 for Denso-Honda contracts. The percentage of a supplier’s business that goes to BMW and Daimler (Mercedes-Benz) is the measure of that firm’s “German-Quality” measure.

A.6 Wages

County level wages are constructed by dividing first quarter manufacturing payroll from County Business Patterns by employees at the county level for manufacturing sectors. This is then deflated using the July CPI and annualized to correspond to an annual wage. The percentage of high school graduates within each county is then projected off of the log real wage in order to partially control for labor quality in each county.

In order to obtain the wage measure for a random location, these county level wage measures are then smoothed using the MBA (multilevel b-spline calculation) package in R.

A.7 Firm Concentration

The firm concentration for each point is computed using the “density.ppp” kernel density function in the spatstat package of R. For firm density, a slightly different criteria is used, where any establishment with above 30 employees in at least one year is included (instead of needing 50 in the year of record). An adjustment factor of .2 is used for the standard deviation of the Gaussian kernel.

A.8 Part Weight by Value

The weight by value measure is constructed by using the import data described above. For each category match, I compute the weight by value by summing up the value and weight (in kg) over imports from all countries for that given part. I then deflate the value into year 2000 dollars, and aggregate the value and weight data over all years. Dividing the aggregated weight by the aggregated value, I obtain the weight by value measure used in the paper (which is in units of 100s of Mg/dollar).

A.9 Estimation of State Unionization Rate

The state unionization rate measure used in this paper is the predicted probability of a manufacturing employee having a union in his/her workplace in 2007. I estimate this probability using the Current Population Survey data from 1990-2009 and a logit binary choice framework. I estimate this probability using year, industry, and state dummy variables and using the earnings weights in the CPS.

A.10 Estimation of the Union Gradient

The location simulations require a continuous and convex approximation of the state unionization rate. Continuity is necessary to use gradient methods and convexity is extremely helpful in finding the optimal point.

I divide the section of the United States used for the simulation in section 6 into a grid and estimate a quadratic spline in the y coordinate (measured using the US National Atlas Projection) over the area, with a knot at the median coordinate. The parameters of this estimation are available upon request.

B Proof of Lemma 1

Proof. The profit of firm f in market r is given by equation (3), which can be rewritten

$$\begin{aligned} E[\pi_{rf}] &= Pr(C_{rf} \leq M_{rf})(E[M_{rf} - C_{rf}|C_{rf} \leq M_{rf}]) \\ &= Pr(C_{rf} \leq M_{rf})(E[M_{rf}|C_{rf} \leq M_{rf}]) - Pr(C_{rf} \leq M_{rf})E[C_{rf}|C_{rf} \leq M_{rf}] \end{aligned}$$

Since

$$E[M_{rf}] = Pr(C_{rf} > M_{rf})E[M_{rf}|C_{rf} > M_{rf}] + Pr(C_{rf} \leq M_{rf})E[M_{rf}|C_{rf} \leq M_{rf}]$$

it follows that

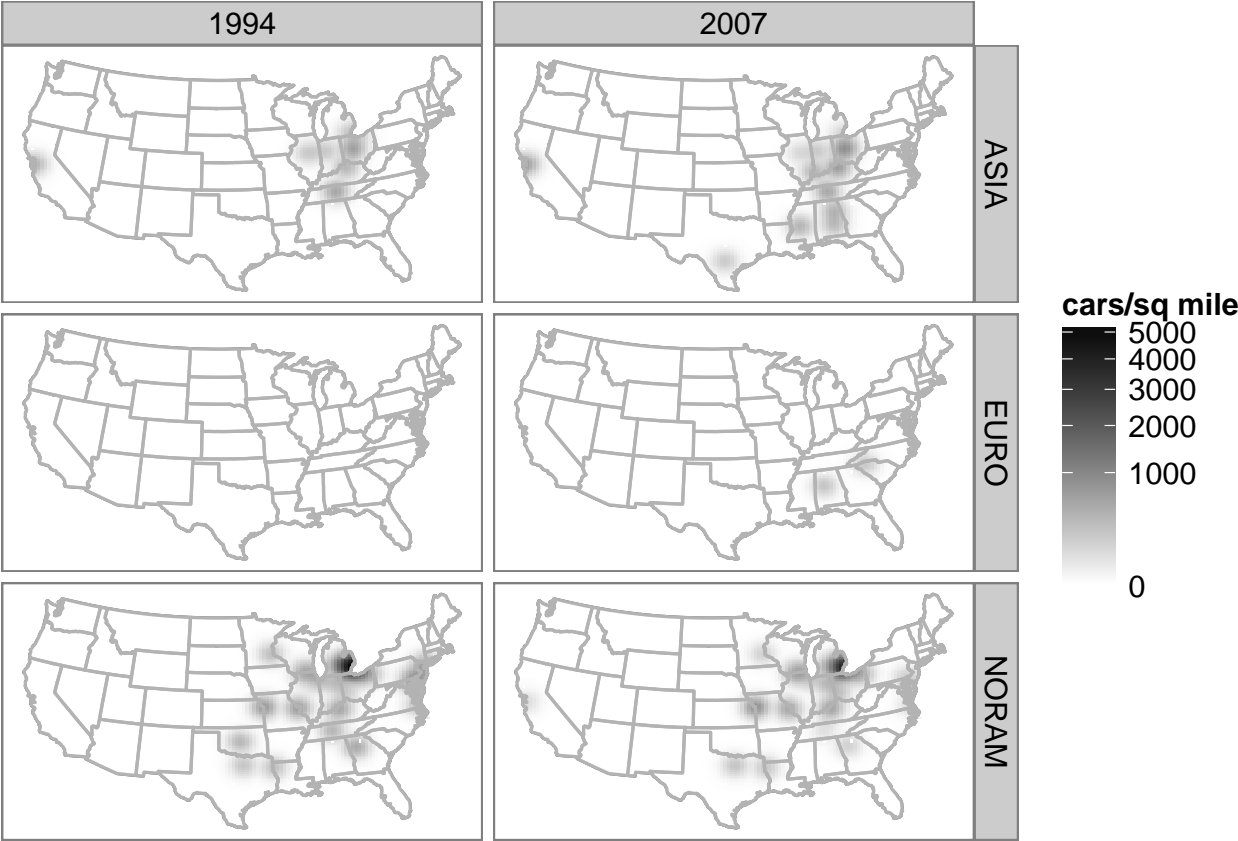
$$\begin{aligned} E[\pi_{rf}] &= E[M_{rf}] - Pr(C_{rf} > M_{rf})E[M_{rf}|C_{rf} > M_{rf}] - \\ &\quad Pr(C_{rf} \leq M_{rf})E[C_{rf}|C_{rf} \leq M_{rf}] \end{aligned}$$

Which simplifies to

$$\begin{aligned} E[\pi_{r,f}] &= E[M_{r,f}] - E[\min(M_{r,f}, C_{r,f})] \\ &= E[M_{r,f}] - E[N_f] \end{aligned}$$

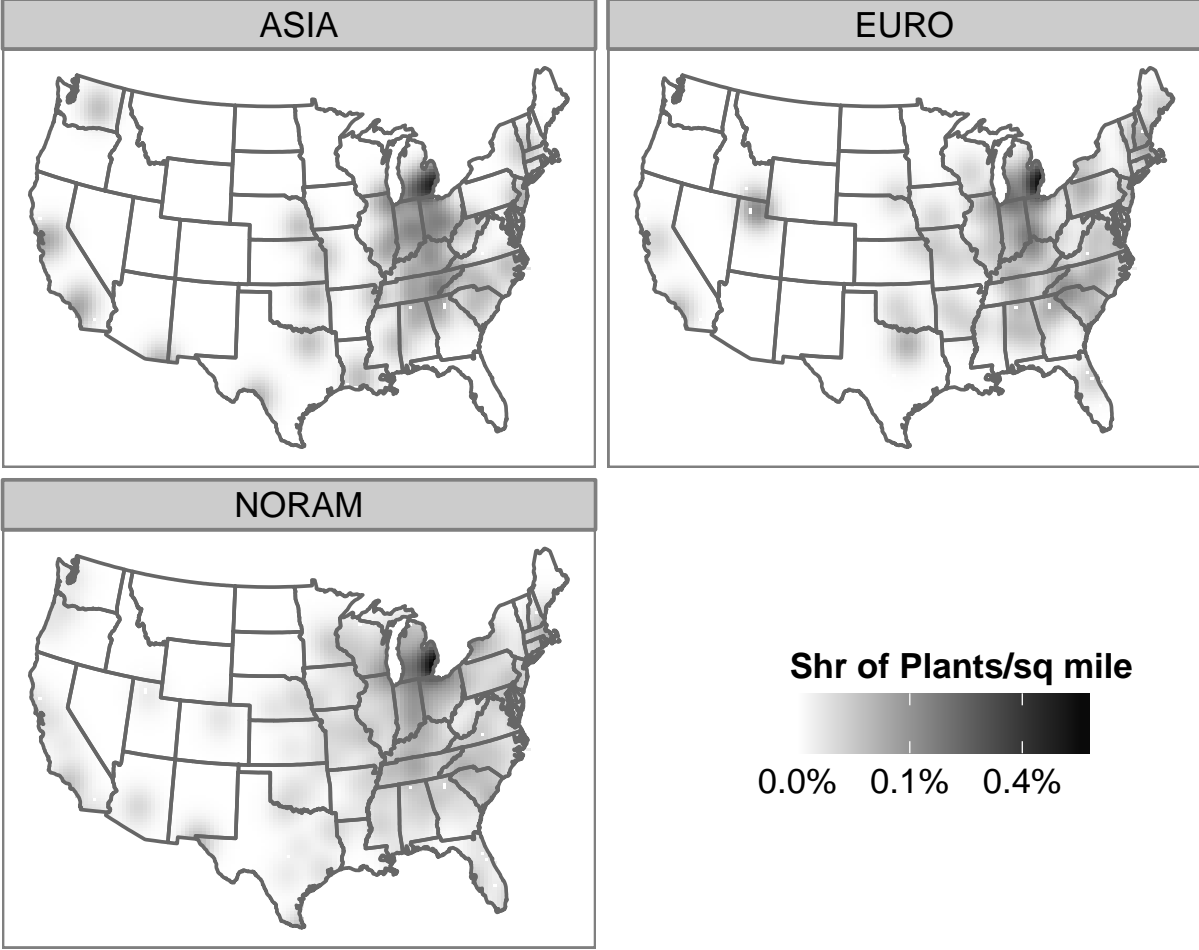
□

Figure 1: Density of Assembler Production in 1994 and 2007



Note: This density was constructed using the 1994 and 2007 production data for United States assembler plants obtained from Ward’s Automotive Database. A kernel smoother in the spatstat package in R was applied to the data to obtain these maps. The scale is a square-root scale. The maps are divided by year and assembler continent of origin.

Figure 2: Density of Supplier Plants in 2007



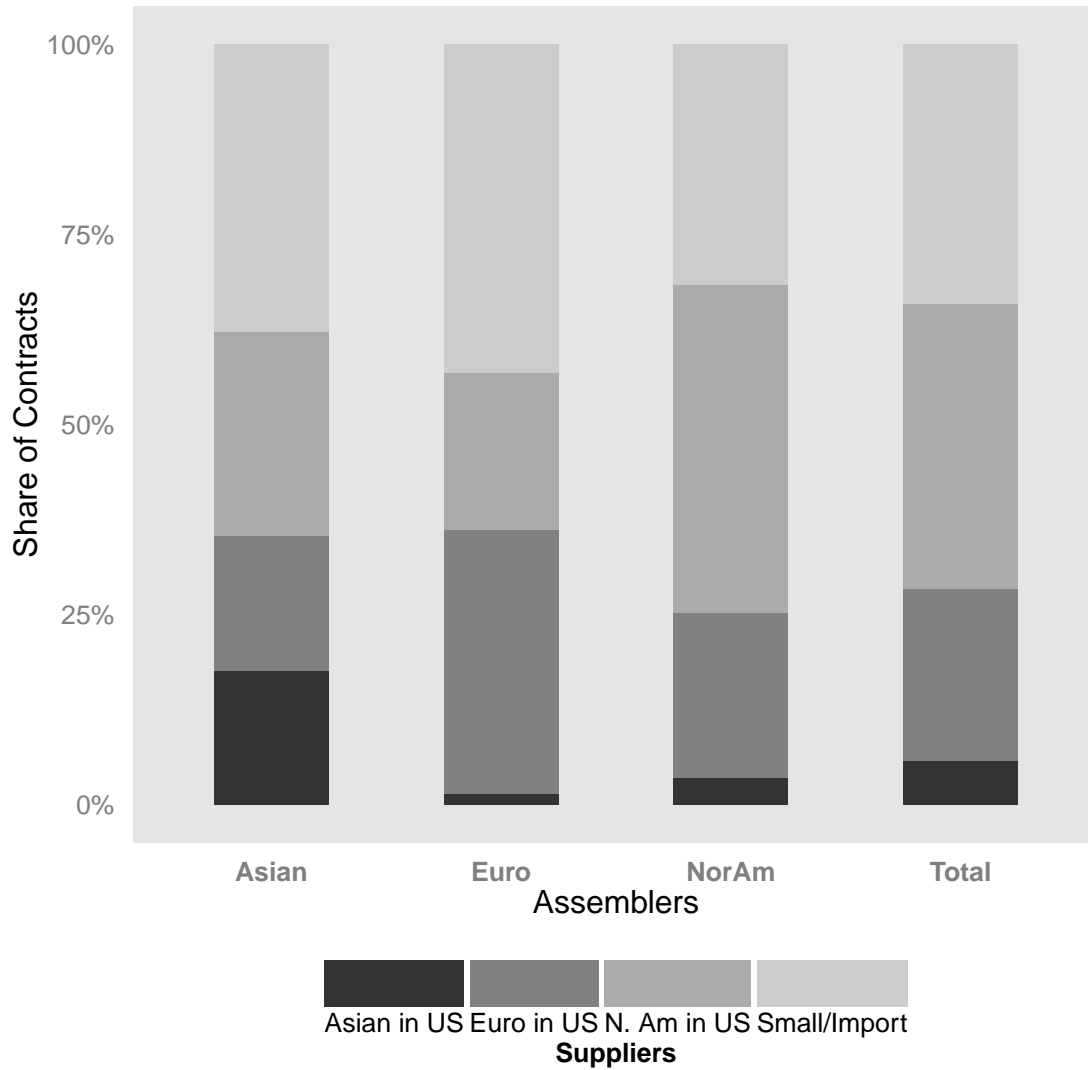
Note: This density was constructed using the set of supplier plants in the NETS data that were from firms in the Automotive News North American Top 150, using the winnowing criteria described in the text. A kernel smoother in the spatstat package in R was applied to the data to obtain this map. The maps are divided by year and supplier continent of origin. The scale is a square root scale.

Figure 3: Geographic Centroid of Supplier Firms' plants



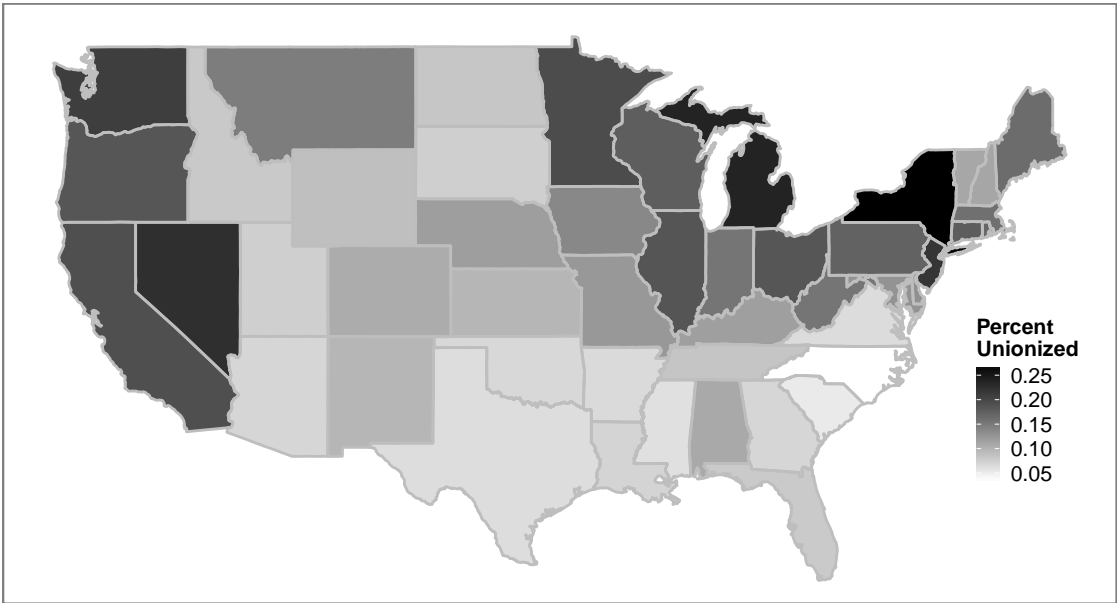
Note: Each data point is the the geographic mean (centroid) of the included plants of one included firm (see text for inclusion criteria). This is the union taken over all years from 2001-2008.

Figure 4: Who Supplies Whom By Continent



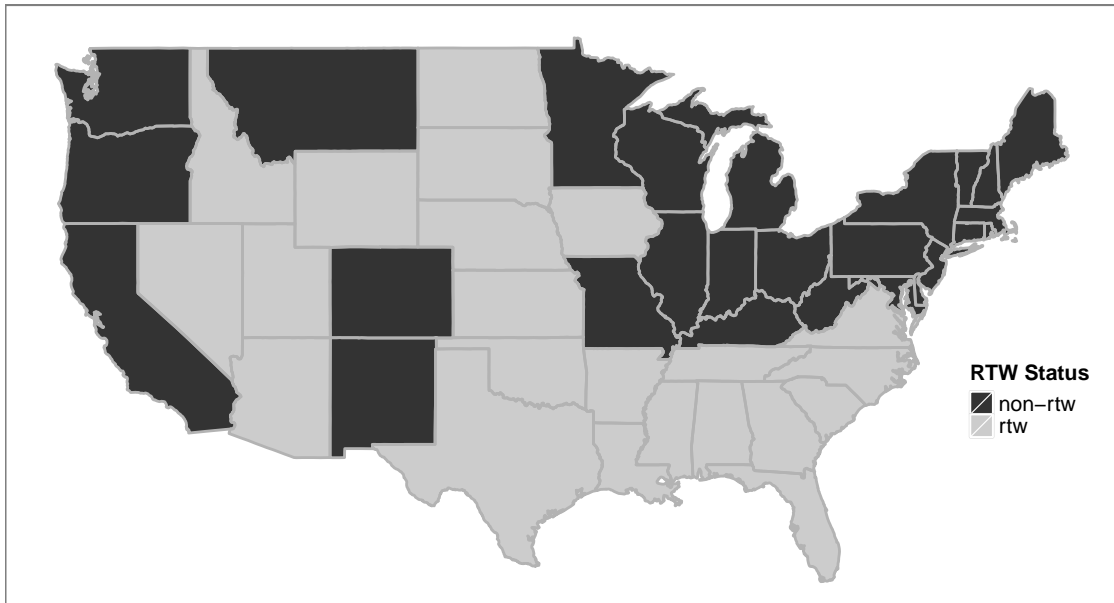
Note: This plot summarizes 13,549 Model/Part/Supplier observations from the WSW Dataset. The small/import category indicates that the given part was supplied by a firm without any plants that met the winnowing criteria described in section A.1.

Figure 5: Probability of Manufacturing Employee Having Union at Workplace in 2007



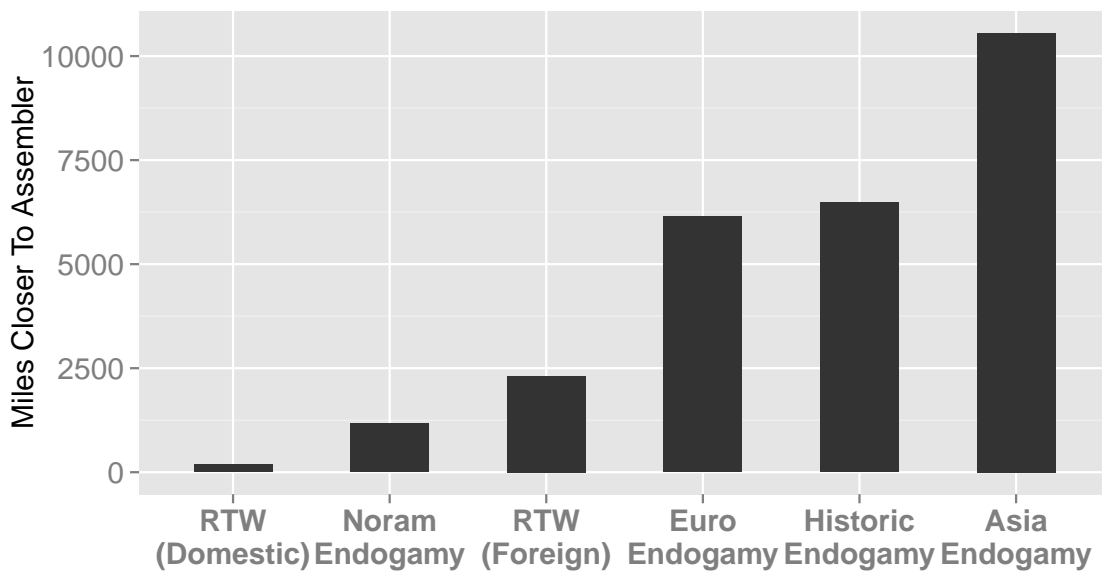
Note: This variable is constructed by estimating the probability of a worker having a union in his/her workplace using year, state, and industry dummies. I use the March CPS micro-data from 1990-2008 for all full time employees. This graph shows the probability that a worker in a manufacturing firm has a union in their workplace in 2007.

Figure 6: State Right-To-Work Status in 2007



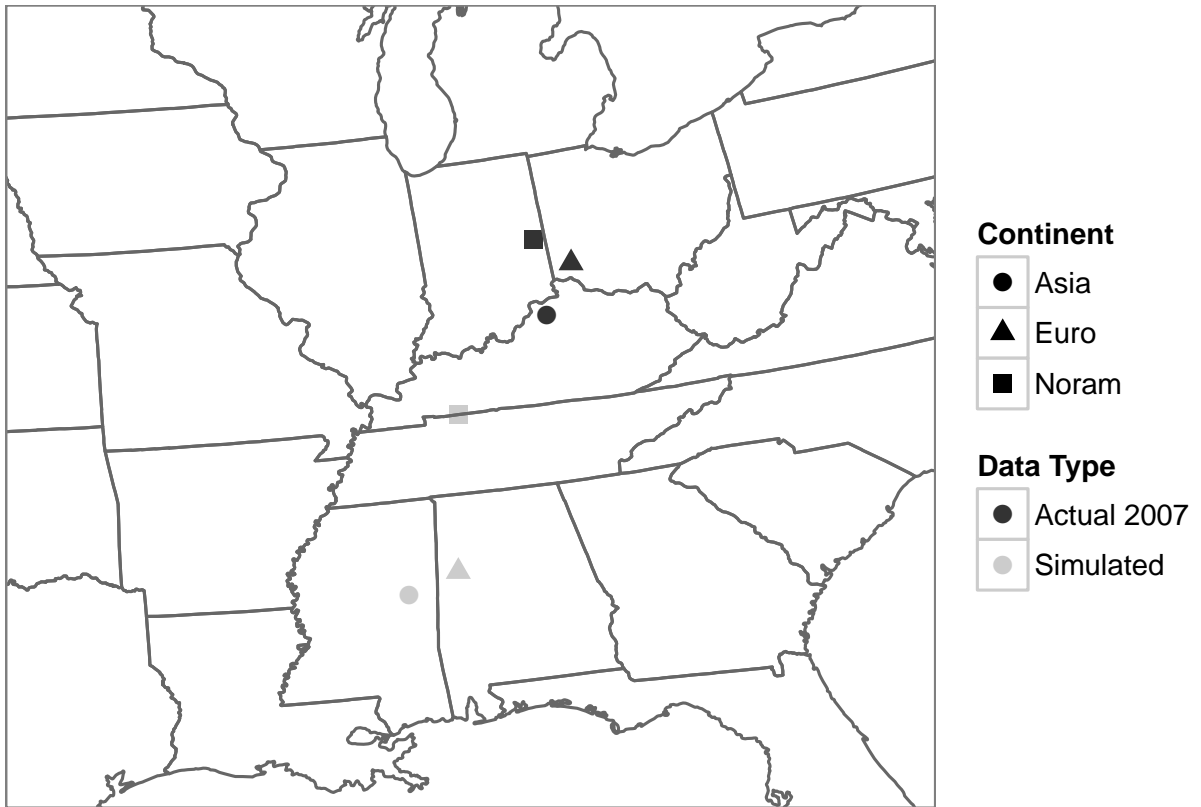
Note: Data taken from Department of Labor classification of right-to-work states.

Figure 7: Cost Equivalent Variable Costs in Terms of Assembler Proximity



Note: This graph is based on the “global” specification. Driving time was converted in to miles using an average travel time of 60 miles per hour.

Figure 8: Variable Cost Equilibrium and Actual Mean Supplier Plant Locations - 2007



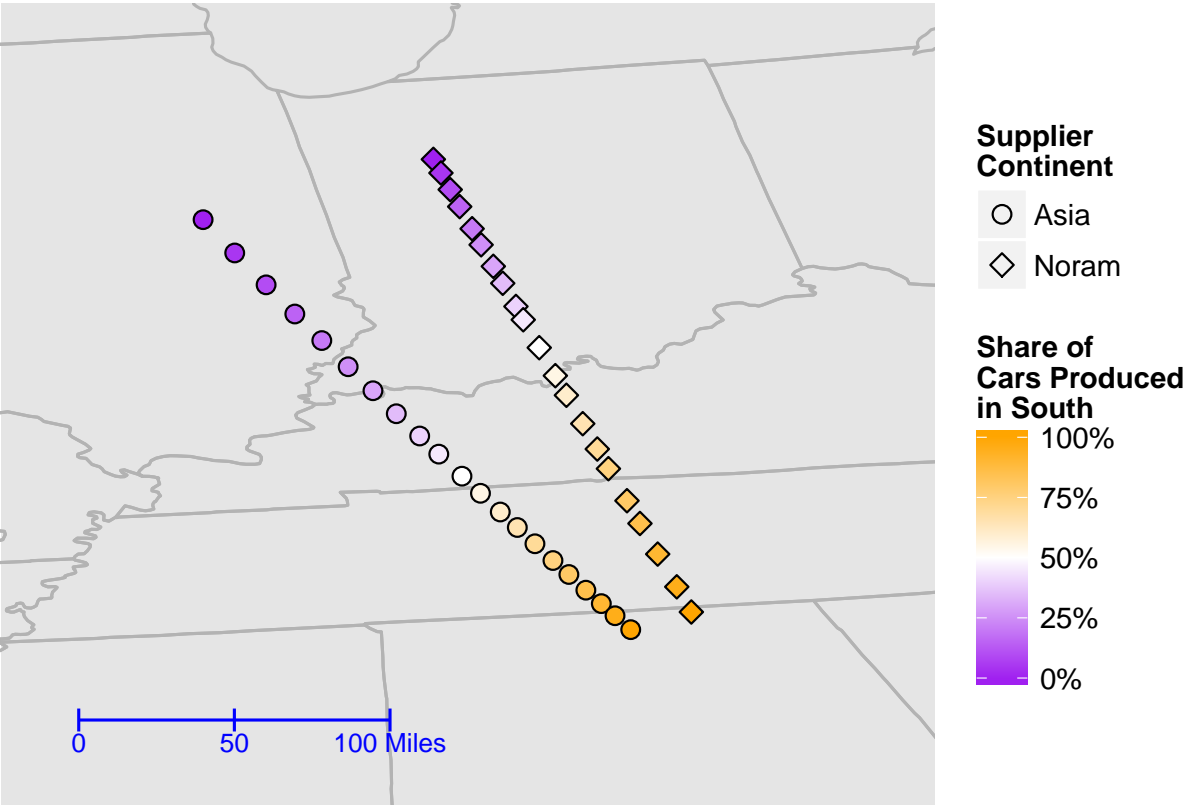
Note: This map is based on the “dist2” specification. “Continent” refers to the continent of origin of the supplier plants. The mean plant location for each firm type (continent of origin) is shown.

Figure 9: Labor and Distance Costs Equilib. Mean Supplier Plant Locations - 2007



Note: This map is based on the “dist2” specification. The Asian and European points in the “just labor” specification are on top of each other. “Continent” refers to the continent of origin of the supplier plants. The mean plant location for each firm type (continent of origin) is shown. See the text for details.

Figure 10: Equilibrium Plant Locations – Locate Just on the Basis of Distance Costs



Note: This map is based on the “dist2” specification. “Continent” refers to the continent of origin of the supplier plants. The mean plant location for each firm type (continent of origin) is shown.

Table 1: Sample Who Supplies Whom Data

Yr	Model	Part Category	Part	Supplier
2003	Ford Focus	Brake Parts	Brake Pads	Delphi
2003	Honda Civic	Brake Parts	Brake Pads	Delphi
2006	Honda Civic	Windshield	Windshield Glass	Denso
2006	Honda Civic	Brake Parts	Brake Brackets	Denso

Note: This is not actual data from the dataset, which is protected by a confidentiality agreement.

Table 2: Variable Cost Function Parameter Estimates

	Base	Wage	Global	Agglom	Wgt
Proximity to Assembler (Hours Drive)	0.008 <i>0.002</i>	0.010 <i>0.002</i>	0.009 <i>0.002</i>	0.008 <i>0.002</i>	0.006 <i>0.002</i>
Proximity X Big Part	0.028 <i>0.004</i>	0.030 <i>0.005</i>	0.033 <i>0.004</i>	0.030 <i>0.005</i>	
Proximity X Wgt By Value					0.022 <i>0.008</i>
Asian Endogamy	-1.64 <i>0.09</i>	-1.59 <i>0.10</i>	-1.53 <i>0.09</i>	-1.64 <i>0.09</i>	-1.64 <i>0.09</i>
European Endogamy	-0.91 <i>0.09</i>	-0.89 <i>0.09</i>	-0.89 <i>0.09</i>	-0.90 <i>0.09</i>	-0.91 <i>0.09</i>
North American Endogamy	-0.18 <i>0.07</i>	-0.17 <i>0.07</i>	-0.17 <i>0.07</i>	-0.16 <i>0.07</i>	-0.18 <i>0.07</i>
Historic Endogamy	-1.13 <i>0.05</i>	-1.22 <i>0.05</i>	-0.94 <i>0.06</i>	-1.12 <i>0.05</i>	-1.12 <i>0.05</i>
Right to Work State (RTW)	-0.46 <i>0.07</i>	-0.24 <i>0.06</i>	-0.34 <i>0.06</i>	-0.48 <i>0.06</i>	-0.45 <i>0.07</i>
North American X RTW	0.28 <i>0.09</i>	0.70 <i>0.11</i>	0.31 <i>0.09</i>	0.44 <i>0.09</i>	0.32 <i>0.09</i>
Distance to Detroit (Miles)	0.07 <i>0.01</i>	0.02 <i>0.01</i>	0.02 <i>0.01</i>		0.06 <i>0.01</i>
Firm Concentration				-1.19 <i>0.17</i>	

Note: Standard errors are in italics below the point estimates. A linear year trend and separate intercepts for each assembler continent of origin are included. Details of the estimation are in the text.

Table 3: Cost Function Parameter Estimates

	Union	Dist2
Proximity to Assembler (100s Miles)	0.015 <i>0.005</i>	
Proximity X Big Part	0.06 <i>0.01</i>	
Proximity to Assembler Squared (100s Miles)		0.00067 <i>0.00025</i>
Proximity X Big Part Squared		0.0037 <i>0.00095</i>
Asian Endogamy	-1.50 <i>0.09</i>	-1.51 <i>0.09</i>
European Endogamy	-0.88 <i>0.09</i>	-0.89 <i>0.09</i>
North American Endogamy	-0.19 <i>0.07</i>	-0.19 <i>0.07</i>
Historic Endogamy	-0.95 <i>0.06</i>	-0.96 <i>0.06</i>
State Union Rate	1.73 <i>0.43</i>	1.67 <i>0.38</i>
North American X Union Rate	-1.00 <i>0.53</i>	-1.46 <i>0.53</i>
Distance to Detroit (100s Miles)	0.02 <i>0.01</i>	
Distance to Detroit Squared		0.0001 <i>0.0004</i>

Note: Standard errors are in italics below the point estimates. A linear year trend, separate intercepts for each assembler continent of origin, German-quality, and global endogamy measures are included. Details of the estimation are in the text.

Table 4: Change in Costs of Parts Production By Assembler – National Union Environment

	Midwest	South
Asian	5.4	3.1
European	N/A	3.4
North American	3.1	2.7

Note: These numbers are the decrease in costs as a result of the counterfactual policy. They are reported as a share of the reduction in costs that would come from eliminating all distance costs within the U.S.

Table 5: Change in Costs of Parts Production By Assembler – Labor Cost Parity

	Midwest	South
Asian	8.4	5.7
European	N/A	4.8
North American	9.4	8.6

Note: These numbers are the decrease in costs as a result of the counterfactual policy. They are reported as a multiple of the reduction in costs that would come from eliminating all distance costs in the U.S.