Distribution Costs and The Size of Indian Manufacturing Establishments

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Abstract

The sale of manufacturing goods involves costs of distribution such as shipping, insurance and commissions. Using micro-data from India's Annual Survey of Industries, we document that larger plants spend a larger share of their sales on distribution. We ask to what degree these distribution costs act as a constraint on larger firms and can explain the high employment share in small plants. To explore this mechanism, we develop a simple general equilibrium model in which heterogeneous firms face fixed and variable costs of distributing their products to customers. Firms selling higher quality products sell to more distant customers and incur higher distribution expenses. We carry out some preliminary quantitative exercises to explore how much TFP increases in the distribution sector affect aggregate consumption and the firm size distribution.

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1. Introduction

An important step in the sale of manufactured products is distributing products to consumers. This process involves costs from shipping, transit insurance and commissions to intermediaries. These costs may be particularly high in developing countries, due to poor physical infrastructure, unproductive distributors or monopoly power of intermediaries (see WTO (2004) or Atkin and Donaldson (2015)). Improvements in transportation infrastructure have also been prioritized by policy makers; in 2016 the World Bank's transport commitments amounted to $57.7 billion, close to 20% of their total lending portfolio (World Bank (2017)).

In this paper we explore the importance of the productivity of the distribution sector for the development of Indian manufacturing. In recent years an important strand of the international trade literature has focused on how reductions in international trade costs lead to reallocation of inputs across firms, exit of small firms and increases in sectoral productivity.[1] Higher international trade costs are therefore associated with lower productivity and smaller median firm size. However, *intranational* trade costs could have similar effects, potentially contributing to the huge differences in manufacturing productivity and median plant size between India and the U.S. (see Bento and Restuccia (2017)). Figure 1 shows that productivity (TFP) in the Indian distribution sector increased by 50% between 1995 and 2009.[2] Meanwhile, between 1993 and 2011, the aggregate share of distribution expenses in total costs for Indian manufacturing plants fell from 3.9% to 2.3%. We therefore ask: what is the impact of these reductions in *intranational trade costs* on manufacturing productivity and on the size distribution of manufacturing plants?

Our first contribution is to document a novel stylized fact using micro-data

[1]These mechanisms are present in trade models with firm heterogeneity following Melitz (2003). See Trefler (2004), among others, for supporting empirical evidence of the impact of tariff reductions.

[2]We classify wholesale, retail and transportation industries to be part of the distribution sector. Average TFP growth was 25% across all sectors between 1995 and 2009.

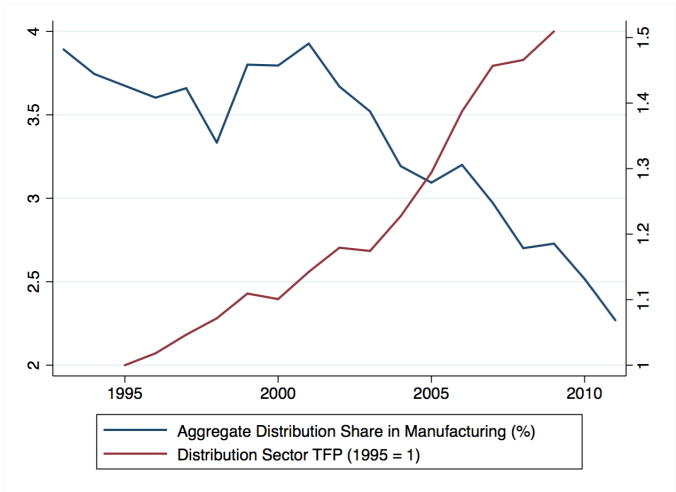
from the Indian Annual Survey of Industries (ASI); the share of distribution expenses in total costs (the distribution share) is increasing in plant size for formal manufacturing plants. This result holds when comparing plants operating within the same district and narrowly defined industry. It is also robust to using different measures of size and to restricting our sample to non-exporters. We find that the distribution share is 1.5 percentage points larger for plants in the top decile of the plant-size distribution relative to plants in the bottom decile.[3] The fact that larger Indian manufacturers use distribution services more intensively than smaller manufacturers implies that they are potentially more affected by the quality of distribution services and transportation infrastructure than smaller manufacturers.

In order to explain these facts and conduct counterfactuals, we develop a two-sector general equilibrium model in which a continuum of firms and consumers are distributed along a circle. Manufacturing firms are heterogeneous in the quality of the products they produce. They choose where to sell and how much to sell at each location, subject to fixed and variable costs. The sale of manufactured goods requires the purchase of distribution services from the distribution sector. Shipping longer distances requires a larger quantity of distribution services. Only high quality firms are profitable enough to access more distant markets. They are therefore larger and ship longer distances on average. Given that distribution costs increase with distance, longer average shipping distances implies that larger plants have a higher distribution share. The main mechanism in the model is as follows. When the productivity of the distribution sector increases, the price of distribution services falls. High quality firms therefore choose to sell their products in more distant markets. The increase in competition then forces out lower quality firms. Given that low quality firms are smaller, both median firm size and average sectoral productivity (quality) increase.

We calibrate our model to match three moments, the elasticity of distribu-

[3] Plants in the bottom decile have an average distribution share of 1.5%.

Figure 1: Aggregate Distribution Share of Sales (Indian ASI, 1993-2011)



Note: the left axis plots the aggregate distribution share of sales from 1993 to 2011 for formal Indian manufacturing plants. Further details regarding the data are available in Section 2. The right axis plots TFP in the Indian Manufacturing sector and the Indian Distribution sector from 1995 to 2009 (1 in 1995). The data comes from the World Input Output Database (WIOD). Sectoral TFP is constructed as $Y_s/(K_s^{\alpha_s} L_s^{1-\alpha_s})$, where Y_s is real value added (in \$1995), K_s is the real stock of capital (in \$1995), and L_s is total employment. α_s is the average cost-based capital share across all years in the sample (assuming a capital rental rate of 20%).

tion cost with respect to size, the aggregate distribution share and the average distribution share in 1995. We simulate an increase in the relative productivity of the distribution sector that matches the observed increase between 1995 and 2009. Our model predicts an increase in measured manufacturing TFP of 1.8% and an increase in median firm size of 5.2% as smaller plants exit and more productive plants gain market share. The increase in median firm size stems largely from the fact that we match the elasticity of distribution costs with respect to firm size. We show that a model without this mechanism would only predict a 1.8% increase in firm size.

Important contributions to the literature on intranational trade costs in developing countries include Atkin and Donaldson (2015) and Donaldson (2018). We add to these by directly measuring reported distribution expenses by manufacturers, rather than by inferring trade costs from price differentials or a gravity model. Our model is based on a closed-economy continuous-location version of Melitz (2003) and Arkolakis (2010). Our main difference relative to the latter is that we focus on how *variable* distribution costs change with distance, rather

than *fixed* costs. This is crucial for matching our empirical finding that the distribution share increase with firm size. Our paper also relates to an important literature on differences in the firm size distribution between developed and developing economies, including recent work by Hsieh and Olken (2014) and Bento and Restuccia (2017).

The rest of the paper is structured as follows. In Section 2. we present our empirical results, in Section 3. we lay out our model, and in Section 4. we perform our quantitative exercises.

2. Distribution Costs in Indian Manufacturing

In this section we discuss the dataset used in this paper. We then present a number of novel stylized facts about the how outward distribution costs as a share of sales vary across the plant size distribution, and discuss our interpretation of these findings.

2.1. Data Description

The dataset we use is the Indian Annual Survey of Industries (ASI). The survey is carried out annually, and our sample period is 1993 to 2011.[4] The ASI is a nationally representative survey of the formal manufacturing sector in India. The coverage is all plants with more than 10 workers using power, and all plants with more than 20 workers not using power. Plants fall into two categories: *Census* and *Sample*. *Census* plants are surveyed every year, and consist of plants with workers above a given threshold as well as all plants in 12 of the industrially 'backwards' states.[5] *Sample* plants are sampled at random every year within each state $\times$ 3-digit industry group, and sampling weights are provided.

[4]Note that the surveys cover accounting years (e.g. 1996-1997), but we will refer to each survey by the earlier of the two years covered.

[5]The exact threshold number of workers varies over the course of our period. See Table 4 for more details regarding sampling changes in the ASI over time.

Our main interest is in the reporting of outward distribution expenses (referred to as '*other distributive expenses*').[6] As per the ASI manual, this variable includes the value of outward transport costs, rebates, commissions, transit insurance of goods sold, and packing fees for goods sold.[7] It is important to note that this does not include *fixed* distribution costs, such as the costs of advertising, finding distributors or setting up a warehouse. We therefore believe that it is appropriate to think of this measure of distribution expenses as capturing the variable component of distribution costs paid by the plant. In the 1993-1997 ASI survey years, total outward distribution costs are broken down into the following subcomponents: transport costs, rebates, commissions and other. In the data these account for 46.4%, 17.8%, 12.1% and 23.7% of aggregate outward distribution expenses respectively. The measurement of outward distribution expenses at the plant-level is quite unique to the ASI. We know of no other plant-level surveys in which distribution costs are reported directly; typically the value of products shipped is reported net of distribution costs.[8]

The other main variables we use are plants' revenues, employment, labor costs, capital stocks and intermediate input expenditures. Revenues include the gross value of product sales, changes in inventories and other sources of revenue. Employment includes both paid and unpaid labor. Labor costs include wages and salaries, bonuses, contributions to the firms' provident (pension) fund, and other welfare expenses. The capital stock is measured as the average of beginning and end of year book value of the net fixed capital stock. Intermediate inputs include materials and fuels consumed as well as other expenditures. We also construct a harmonized sectoral classification consisting of 50 manufacturing sectors that are consistently defined throughout our time period.[9] Details on the construction of variables and sectoral classifications are

[6]This is reported in Block J, column 10 of the schedule in more recent survey years.

[7]See p.37 of the 2014 Instruction Manual for the Annual Survey of Industries (Concepts, Definitions and Procedures).

[8]This is the case for the Annual Survey of Manufactures collected by the U.S. Census office.

[9]The official sectoral classification (NIC) changed in 1987, 1998, 2004 and 2008. We use official NIC concordances to construct our harmonized classification.

provided in the Data Appendix.

2.2. Distribution Costs and Plant Size

The novel fact presented in this paper is that outward distribution costs as a share of gross sales (which we refer to as the *distribution share*) are increasing in plant size. We construct the distribution share as:

$$\text{distribution share} = \frac{\text{outward distribution costs}}{\text{gross sale value - taxes}}$$

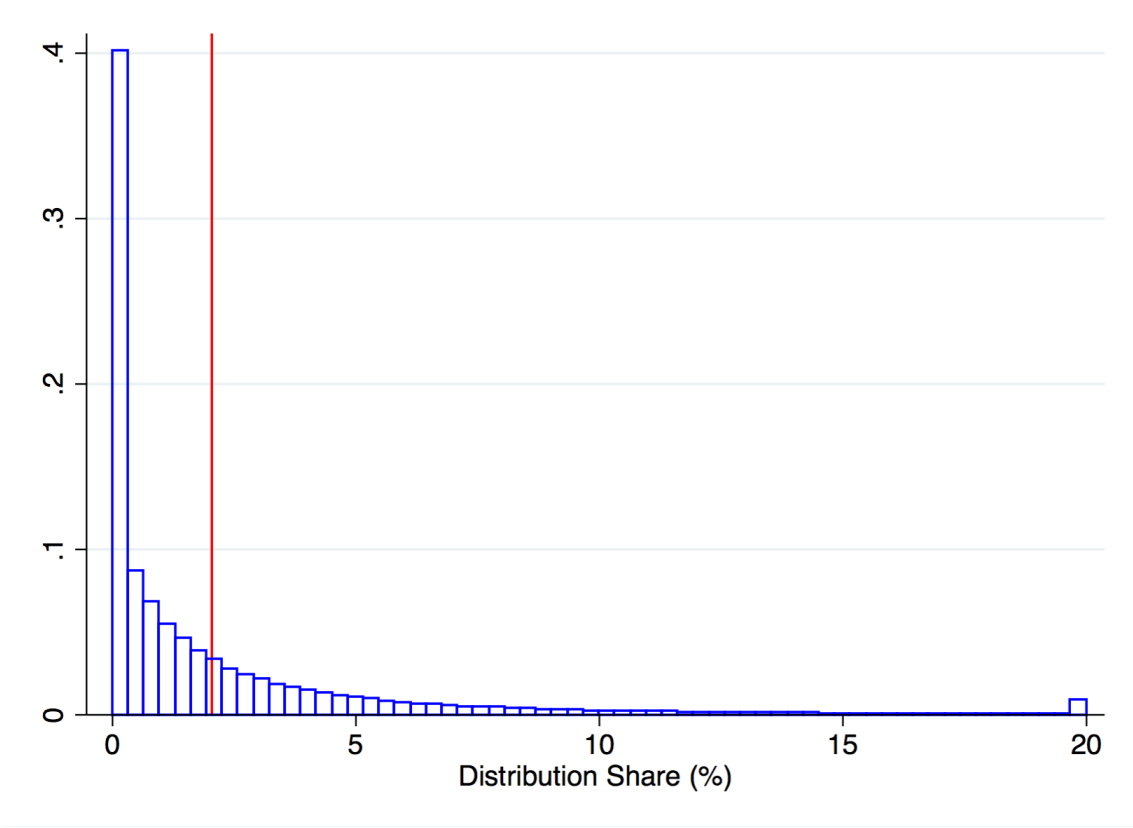
Figure 2 shows a histogram of the distribution shares of Indian plants in the ASI.[10] The median distribution share is .7% of gross sales (net of taxes), the mean is 2.0% and the aggregate is 3.3%. Figure 3 shows our main empirical finding: larger plants have higher distribution shares. The figure plots the distribution share against log(employment) in a binned scatterplot. Both variables are residualized on a full set of industry×year×district fixed effects in order to remove any location or industry specific variation that could drive differences in distribution shares across plants.[11] The graph is therefore based on a comparison of two plants that are located close to one another geographically and operate in the same industry but differ in terms of their size.

The relationship between the distribution share and log(employment) is strikingly linear and shows sizeable differences across plants in the importance of distribution expenses. While the smallest plants in our sample spend just about 1% of sales on distributing their products, the distribution share goes up to nearly 4% for the largest plants. As can be seen in Figure 1 the aggregate dis-

[10] We winsorize the distribution share at 20% following recommendations in the 2011 Instructions to Field Officials on Annual Survey of Industries (page A-58 row 75). This is relevant for 1.2% of observations.

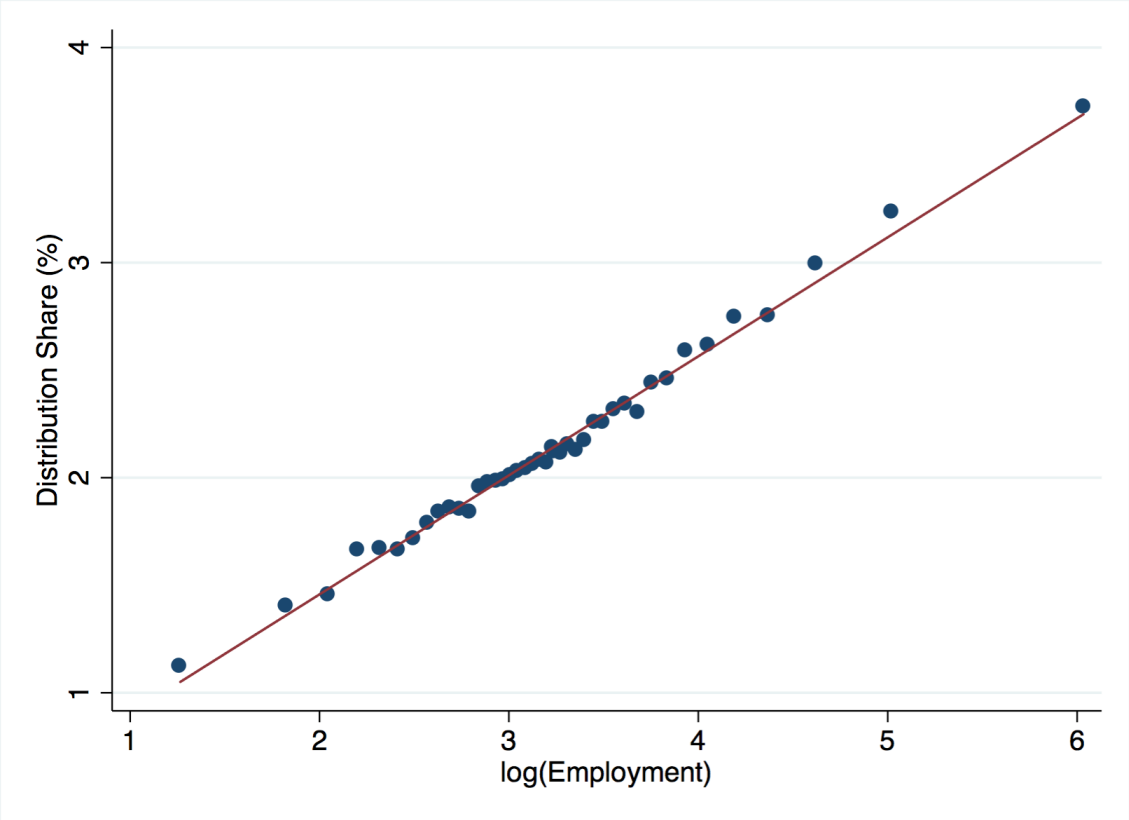
[11] We use the most detailed industry classifications available in each year, 4-digit NIC87, 5-digit NIC98 and 5-digit NIC04. There are between 400 and 700 manufacturing industries at this level of disaggregation. In 2001 there were 593 districts in India, though the number has changed over time. The ASI surveys we have available to us for the years 2008-2011 do not include the district in which the plant is located, so we only include the ASI survey years 1993-2007 in constructing this figure.

Figure 2: Distribution Share Histogram for ASI Plants (1993-2011)



Note: the histogram pools together data for all ASI year between 1993 and 2011, taking into account the sampling weights. The red line indicates the mean distribution share (2%). 24.9% of plants report a distribution share of 0%.

Figure 3: Binned Scatter Plot of Distribution Share Against Log(Employment)



Note: the figure is a binned scatter plot of plants' distribution shares against log(employment). 50 equally sized bins are used. The line of best fit is shown in red. The ASI survey years used are 1993-2007. Both the distribution share and log(employment) are residualized on full set of industry×year × district fixed effects. We use the most detailed industry classifications available in each year, 4-digit NIC87, 5-digit NIC98 and 5-digit NIC04. There are between 400 and 700 manufacturing industries at this level of disaggregation. In 2001 there were 593 districts in India, though the number has changed over time.

tribution share averages 3.3% between 1993 and 2011. Considering that the distribution share is measured relative to sales, these numbers are not small. In comparison, the aggregate labor share (payments to labor relative to sales) averages 6.1% over the same period.[12] Distribution costs are more than half as important as labor costs for Indian manufacturing plants. We show in the Appendix that the relationship between the distribution share and size is remarkably robust. Figure 5 shows that it holds for alternative measures of plant size, such as output or total intermediates used. Furthermore, all components of distribution expenses as a share of sales are increasing with respect to plant size, as shown in Figure 9.

We view the relationship between plant size and the distribution share as being driven by the following two factors. Firstly, the cost of shipping goods within India is increasing in the distance shipped. Secondly, larger plants tend to ship their goods further distances than smaller plants. That transport costs are increasing in distance is a well-established fact in international trade. In addition, Holmes and Stevens (2012) provide evidence that larger U.S. manufacturing plants ship their products further distances within the U.S. than smaller plants.[13] Due to a lack of comparable data we unfortunately cannot replicate the findings in Holmes and Stevens (2012) for India. However, it seems reasonable to believe that the same forces would be in play in both countries.

While this is an intuitive explanation for the relationship documented in Figure 3, there are a number of alternative factors that could give rise to the observed relationship between plant size and the distribution share. An important concern is misreporting. If small plants fail to report a portion of their distribution expenses we would spuriously infer that distribution costs as a share of sales are increasing in size. This could occur if larger plants have better bookkeeping. Alternatively, smaller plants might be more likely to do their dis-

[12]The average and median labor shares across plants are 16% and 8.2% respectively. Indian plants have high intermediate shares, averaging over 80%.

[13]There is also a large body of work documenting that larger plants export relatively more than smaller plants (Bernard and Jensen (1995)) and that plants with high domestic sales sell to more foreign destinations.

tribution in-house, in which case some of their distribution expenses might be reported as part of their labor costs. While we cannot provide any direct evidence on the frequency of misreporting, we show in Figure 7 that *inward* distribution costs as a share of sales are *decreasing* in plant size.[14] Since we would expect misreporting to affect inward distribution costs in the same way as outward distribution costs it seems unlikely that this is strong enough to drive the relationship shown in Figure 3.

One might also worry that the relationship between distribution costs and size is driven by foreign exports rather than domestic sales. It is indeed the case that Indian exporters tend to be larger than non-exporters and it is likely that the variable costs of exporting abroad are higher than the costs of distributing goods domestically. Fortunately, in the 1997 ASI survey plants reported the value of their exports.[15] Figure 6 shows that the positive relationship between the distribution share and size holds even when we restrict our sample to non-exporters.

Finally, the increasing relationship we document between the distribution share and size is not driven by larger Indian plants having lower markups/profit-margins. If this was the case we should observe that all cost shares are increasing in size and that the share of distribution costs in total costs is flat. However, we showed in Figure 7 that the inward distribution share of sales was decreasing in size. In addition, we document in Figure 8 that the distribution share of costs is also increasing in plant size.[16] We conclude that distribution expenses are therefore a unique component of plants' costs in this respect.

In summary, we view the increasing relationship between plant size and the distribution share as arising from the following two factors: the variable cost of distributing goods is increasing in distance and larger plants ship their goods further distances. As a result, larger plants use distribution services more intensively than smaller plants in India. This makes them particularly affected

[14]Inward distribution expenses include expenses incurred for acquiring and transporting production materials. These are reported in the ASI for the years 1993, 1994 and 1996.

[15]This is the only survey year in which the value of exports was reported.

[16]The distribution share of costs is constructed as distribution expenses / total costs.

by the quality of Indian infrastructure and by the productivity of the distribution sector. We will formalize these relationships in our model in Section 3..

3. Model

3.1. Setup

The model is based on a closed-economy, continuous-location extension of Arkolakis (2010). Time is discrete, agents are risk-neutral and do not discount the future. The economy consist of two sectors, manufacturing and distribution. Manufacturers produce differentiated varieties and purchase distribution services in order to sell their products to consumers across space. We model space in a simple and abstract way: the economy lies on a circle with circumference 1. The key mechanism of the model lies in how large a fraction of the circle firms choose to sell to.

Consumers

At each point along the circle, there is a continuum L of workers.[17] Workers' preferences over varieties feature a constant elasticity of substitution σ. They cannot save or borrow, which gives rise to the following problem (suppressing time subscripts for ease of exposition):

$$\max_{c_l(\omega)} \left(\int_{\omega \in \Omega_l} \psi(\omega) c_l(\omega)^{\frac{\sigma-1}{\sigma}} d\omega \right)^{\frac{\sigma}{\sigma-1}} \text{ s.t } \int_{\omega \in \Omega_l} p_l(\omega) c_l(\omega) d\omega \leq y \tag{1}$$

Varieties differ in their quality $\psi(\omega)$. Higher quality varieties give more utility per unit of consumption. We denote by Ω_l the set of varieties available to a consumer at location l. Ω_l will be different at each point along the circle and is an equilibrium object determined by the selling choices of all firms in the economy. Consumers inelastically supply their unit endowment of labor to

[17] Our setup is perfectly symmetric at every point on the circle.

either the manufacturing or the distribution sector for a wage w. They also receive a share $\frac{1}{L}$ of aggregate profits $\bar{\pi}$. Their income y is therefore equal to $w + \frac{\bar{\pi}}{L}$. These preferences give rise to a standard CES demand equation for a variety with quality $\psi(\omega)$ and price $p(\omega)$:

$$c(\omega) = P^{\sigma-1} \ (w + \frac{\bar{\pi}}{L}) \ \psi(\omega)^{\sigma} \ p(\omega)^{-\sigma} \tag{2}$$

where $P \equiv \left(\int_{\omega \in \Omega_l} \psi(\omega)^{\sigma} p(\omega)^{1-\sigma} d\omega \right)^{\frac{1}{1-\sigma}}$.

Distribution Sector

Firms in the distribution sector are perfectly competitive. They employ labor L_D to produce distribution services d using a constant returns to scale production technology:

$$d = A_D L_D \tag{3}$$

Our perfect competition and constant returns to scales assumptions imply that $p_D = \frac{w}{A_D}$.

Manufacturing Sector

In each period t there is an endogenously determined mass J of manufacturing firms in operation along the circle. Manufacturing firms are heterogeneous along two dimensions: the quality ψ of the variety they produce and their (production) location on the circle. Firms choose both the set of markets (locations on the circle) in which they will sell their product (extensive margin problem) and also the quantity to sell in each market (intensive margin problem). We assume that firms have a constant returns to scale production function, making the extensive and intensive margin problems separable. We will therefore first solve the intensive margin problem and solve for sales and profits in each

possible market. We will then solve the extensive margin problem to determine the optimal set of markets that each firm will sell to.

In order to sell a quantity $q(\psi, n)$ to a consumer located at a distance n along the circle a firm must produce the good, pay a fixed cost $f(n)$ of accessing the market and purchase distribution services $d(n)$ to get the product to the consumer. The fixed cost $f(n)$ depends only on the distance n between the destination market and the production location of the firm.[18] This captures costs associated with establishing and maintaining a distribution network (e.g. finding and contracting with local retailers). We follow Arkolakis (2010) in modeling the marginal cost associated with accessing a market located a distance n away:

$$f(n) = f\,(1-2n)^{-\beta} \tag{4}$$

As in Arkolakis (2010), the functional form chosen captures three important dimensions of the cost of accessing a sales market:

1. $f'(n) \geq 0$. The further away a market is located, the more costly it is to find a distributor there. The parameter $\beta \geq 0$ governs how quickly costs increase in distance.

2. $\lim_{n\to 0} f'(n) > 0$. There is a positive cost of serving the home market ($n = 0$), akin to a standard fixed cost in a model of production with only one market.

3. If $\beta > 0$, $\lim_{n\to\frac{1}{2}} f'(n) = \infty$. Accessing the entire market is prohibitively costly.[19]

Once a firm has paid the fixed cost of establishing a distribution network in a market at a distance n it produces output for sale in that market according to

[18] These fixed costs are in units of labor.

[19] Given that the circle has circumference 1, the furthest market is located at a distance $n = \frac{1}{2}$.

the following Leontiev production function:

$$q(n) = \min\left\{L_p, \frac{d(n)}{1+\epsilon n}\right\}$$

The physical good is produced with a simple linear technology: one unit of labor is transformed into one unit of the firm's good at the factory gate. In order to be sold in a market at a distance n the physical good needs to be shipped there using distribution services $d(n)$. These distribution services are purchased from the distribution sector at unit cost p_D. In order to sell one unit of the good in a market at distance n, the firm needs to purchase $d(n) = 1 + \epsilon n$ units of distribution services. ϵ governs the rate at which the quantity of distribution services required increases with distance. We think of this parameter as capturing certain aspects of the quality of a country's transportation infrastructure. For example, it could be relatively costly to ship goods longer distances (compared to shorter distances) when highways are of poor quality. This would be captured by a high value of ϵ. Given consumers' demand, a firm with quality ψ solves the following profit maximization in each market n:

$$\begin{aligned} \pi^*(\psi, n) = \max_{q,l,d} \quad & p(q(\psi,n))\, q(\psi,n) - w\, l(\psi,n) - p^D\, d(\psi,n) - w\, f(n) \qquad (5) \\ \text{s.t.} \quad & l(\psi,n) = q(\psi,n) \\ & d(\psi,n) = (1+\epsilon n)\, q(\psi,n) \\ & f(n) \quad = f\,(1-2n)^{-\beta} \end{aligned}$$

The second step in the firm's problem consists of choosing its optimal scale, i.e. which parts of the circle it wish to sell to. Given that (i) production of the physical good exhibits constant returns to scale and (ii) both the fixed and variable cost of distribution are monotonically increasing in the distance to the market reached, choosing where to sell to amounts to choosing the furthest customer the firm will sell to. We denote the distance between the firm and

its furthest customer by $n^*(\psi)$, where:

$$n^*(\psi) = \underset{N \in [0,1/2]}{\text{argmax}} \int_0^N 2\pi^*(\psi, n) dn$$

Given that the economy is located on a circle of circumference 1, there are always two locations that are exactly distance n away from the firm, and the maximal market size is $\frac{1}{2}$. We denote by $\pi^*(\psi)$ the resulting optimal per-period profits a firm with quality ψ can achieve:

$$\pi^*(\psi) = \max_N \int_0^N 2\pi^*(\psi, n) dn = \int_0^{n^*(\psi)} 2\pi^*(\psi, n) dn$$

Entry and Exit

There is a large pool of potential entrants into the manufacturing sector. In order to enter, firms pay a sunk cost of entry equal to f_E units of labor. Upon paying this cost, firms discover their quality ψ (i.e. how much consumers like their product). The distribution from which qualities ψ are drawn is exogenous with CDF $g(\psi)$. After observing their quality, firms choose whether or not to remain active. If they do, they receive profits $\pi(\psi, t)$ in every period in which they operate. Quality is constant over time, and so $\pi^*(\psi, t) = \pi^*(\psi)$. In addition, firms are risk-neutral, there is no time discounting and the probability of not receiving an exogenous exit shock is $1 - \delta$ in each period.[20] This implies that the value of a firm with quality ψ is:

$$\sum_{s=0}^{\infty} (1 - \delta)^s \pi^*(\psi) = \frac{\pi^*(\psi)}{\delta}$$

If $\pi^*(\psi) \geq 0$, the firm will choose to remain active and start production. Otherwise it will endogenously choose to exit. We denote by L^E the mass of workers used for entry and by M^E the mass of entrants each period.

[20] The probability δ is independent of the quality of the firm.

3.2. Equilibrium

Given a quality distribution $g(\psi)$, an equilibrium is set of:

1. prices $\{p^D, w, P, \{p(\psi, N)\}\}$
2. quantities $\{L^D, L^E, L^P, \{c(\omega)\}, \{q(\psi)\}, \{l(\psi)\}, \{d(\psi)\}, J, M^E\}$

such that

1. Consumers optimize subject to their budget constraint
2. Active firms optimize subject to their constraints
3. Production = consumption $\forall\omega$
4. The aggregate constraints hold
5. The free entry condition holds

We focus on equilibria that feature a stationary distribution of firms. Every period, the mass of successful entrants exactly offsets the mass of exiting firms. Given that exit is equally likely for all levels of quality and net entry is zero the endogenous distribution of active firm qualities remains constant.

3.3. Features of the Model

In order to illustrate the main mechanisms of the model we start by considering the extreme case where $\beta = \epsilon = 0$. in this special case neither fixed nor variable costs of distributing products vary with the distance between the plant and the consumer. The profit maximization problem laid out in equation 5 is now independent of the market n. This implies that all active firms will sell to the entire circle.[21] All consumers, irrespective of their location l on the circle have

[21] Firms with quality ψ will be active provided that $\pi^*(\psi, n) = \pi^*(\psi) \geq 0$

access to the exact same set of varieties. The economy collapses to a one-location closed-economy version of Melitz (2003).

Now let $\epsilon > 0$. Selling to markets at a further distance requires more distribution services per unit sold. From the firms' perspective, marginal costs are increasing in n. This implies that they will sell less and make smaller profits in markets located further away. They will only serve a market if profits are sufficient to cover the fixed costs f.[22] This gives the following equilibrium expression for $n^*(\psi)$:[23]

$$n^*(\psi) = \frac{1}{\varepsilon}\left(\frac{A_D}{w}\left(\frac{\sigma-1}{\sigma}\right)\left(\frac{L}{f\sigma}\right)^{\frac{1}{\sigma-1}}\psi^{\frac{\sigma}{\sigma-1}} - (A_D+1)\right) \tag{6}$$

Equation 6 provides intuition for the main mechanism in this model. First, higher quality firms choose to sell to more markets. Since their product is of higher quality they makes higher profits in each market. They will therefore find it worthwhile to overcome the fixed costs to reach more distant markets. This feature of the model is what allows us to replicate the main empirical finding from Figure 3: distribution costs as a share of sales are increasing in firm size. We can solve for the distribution share in a market a distance n away:

$$\frac{p_D d(n,\psi)}{p(\psi,n)q(\psi,n)} = \frac{\frac{1+\epsilon n}{A_D}}{1+\frac{1+\epsilon n}{A_D}}\frac{\sigma}{\sigma-1} \tag{7}$$

The distribution share is independent of firm quality conditional on distance n. A firm's total distribution share is then simply equal to the integral over all markets served. Since higher quality firms sell to more distant markets, they will have a larger overall share of sales spent on distributing their products.

We now turn to discussing the role of the parameter ϵ. Consider a *decrease* in ϵ.[24] From equation 6 one can see that a reduction in ϵ will increase $n^*(\psi)$ for

[22] Because $\beta = 0$ we now have that $f(n) = f$

[23] This formula applies to firms whose optimal choices are interior; i.e. they serve a positive fraction of consumers, but not the entire market ($n^*(\psi) \in \left[0, \frac{1}{2}\right)$. There is a positive mass of firms who sell to the whole market: $n^*(\psi) = \frac{1}{2}$

[24] One can think of this as a change in the technological environment that makes it relatively

all active firms. This is intuitive; lowering ϵ is equivalent to a reduction in the marginal cost of selling to each market, leading to an expansion of all firms. In addition to this direct partial equilibrium effect, firm size is affected through general equilibrium effects on the wage. As firms expand they demand more labor, both directly as an input into production and indirectly through their increased demand for distribution services. The wage increases to restore labor market clearing.[25] Because of the higher wage, production costs increase for all firms. This has an important effect on the minimum quality cutoff for active firms. Denote by $\underline{\psi}$ the lowest quality firm that still finds it worthwhile to remain active in equilibrium.[26] We have that:

$$\underline{\psi} = w\left(1+\frac{1}{A_D}\right)^{\frac{\sigma-1}{\sigma}}\left(\frac{\sigma f}{L}\right)^{\frac{1}{\sigma}}\left(\frac{\sigma}{\sigma-1}\right)^{\frac{\sigma-1}{\sigma}} \tag{8}$$

As the wage increases $\underline{\psi}$ increases also. The reasoning for this is similar to that in Melitz (2003). The expansion of high quality (large) firms drives up the wage, making it harder for small firms to compete for workers. This drives out some small low quality firms. The new equilibrium distribution of firms now features larger and higher quality firms. The left panel of Figure 4 illustrates this mechanism by showing the behavior of four key equilibrium objects as a function of ϵ. As ϵ decreases, it the median firm finds it profitable to sell in more distant markets, which entails an increase in its employment. The equilibrium wage, which in this simple model is equal to welfare, increases to restore labor market clearing. The increase in the wage raises the minimum quality cutoff for active firms, thereby changing the identity of the median firm.

The right panel of Figure 4 illustrates the role of β in our model. Increasing β means that the fixed costs of establishing a distribution network increase more rapidly with distance. As a result, all active firms will sell in fewer markets and have a smaller optimal size. The equilibrium wage falls to restore labor market

cheaper to ship long distances.

[25] We have normalized the price index P to 1, which leaves the wage as the only price left to clear markets.

[26] These are firms for which $n^*(\underline{\psi}) = 0$

clearing, thereby lowering the minimum quality cutoff for active firms. This entry of low quality firms then decreases aggregate welfare.

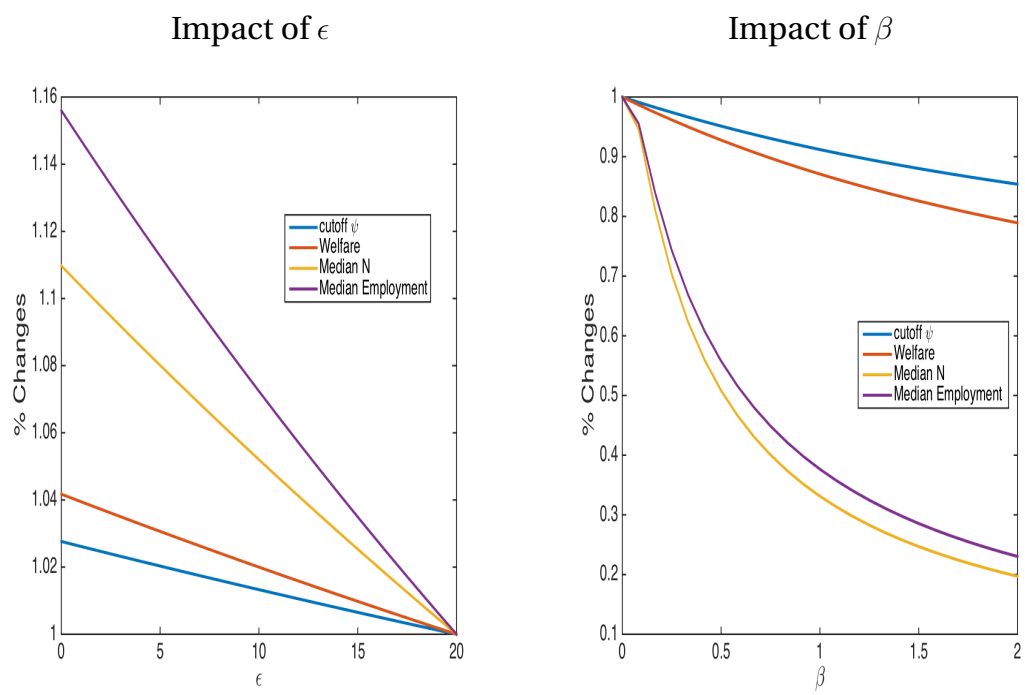


Figure 4: Comparative Statics with respect to ϵ and β

4. Quantitative Analysis

In this section we first calibrate our model to match some salient features of the Indian micro-data. We then feed in to our calibrated model the observed aggregate productivity increase in the Indian distribution and transport sectors between 1995 and 2009 and show the counterfactual change in welfare and median employment predicted by our model. While our counterfactual analysis remains preliminary and our model is quite stylized, we interpret the results of this section as providing benchmark magnitudes for the importance of our mechanism.

4.1. Calibration

We assume that the distribution of qualities $g(\psi)$ is a truncated Pareto with parameters $(\eta, \psi_{min}, \psi_{max})$.[27] This leaves us with 11 parameters in our model to calibrate. The parameters and calibrated values are shown in Table 1. The first 8 parameters shown in Table 1 are relatively standard and we take our calibrated values from the existing literature. There are 3 parameters in the model that are both novel and central. These are labor productivity in the distribution sector (A_D), the rate at which variable distribution costs increase with distance (ϵ) and the rate at which fixed costs increase with each additional market reached (β). We calibrate those to match the following 3 salient data moments.

1. The average distribution share across plants in the ASI, averaged over the years 1993-2011.

2. The aggregate distribution share in the ASI, average over the years 1993-2011.

3. The cross-sectional elasticity of distribution costs with respect to employment in the ASI.

We compare the data moments with the model equivalents in Table 2. The parameter values are shown in Table 1.

4.2. Counterfactuals

We use data from the World Input-Output Database (WIOD) to measure the TFP increase in the Indian distribution sector between 1995 and 2009.[28] The database is at the 2-digit NACE level of aggregation and contains measures of real value-added (in 1995 Rs.), hours worked and the real capital stock (in 1995 Rs.) by industry. We categorize the following industries as being part of the

[27] The upper truncation is mainly for ease of computation, as it makes numerical integrals more precise.

[28] For more details about the WIOD see http://www.wiod.org/home (Timmer et al. (2015)).

Table 1: Calibration of basic 8 parameters

	Parameter	Value
Minimum of Truncated Pareto Distribution	ψ_{min}	.5
Maximum of Truncated Pareto Distribution	ψ_{max}	3
Aggregate Labor	L	1
Fixed Cost	f	.01
Fixed Entry Cost	f_E	.05
Exit Rate	δ	.05
Pareto Shape Parameter	η	4.2
Elasticity of Substitution	σ	3
Rate Distribution Costs $\uparrow$ With Distance	ε	20
Productivity of Distribution Sector	A_D	70
Rate Fixed Costs $\uparrow$ With Distance	β	2

Table 2: Key moments: data targets and model equivalents

Moment	Data	Model
Elasticity of distribution costs wrt size	1.20	1.21
Aggregate distribution share	3.5%	3.5%
Average distribution share	2.2%	2.0%

distribution sector: Inland Transport, Air Transport, Water Transport, Retail Trade and Wholesale and Commission Trade. Figure **??** plots the time-series of TFP in the distribution sector as well as the time-series of TFP in manufacturing. While manufacturing TFP is mostly flat from 1995 to 2009, TFP in the distribution sector increased by 51% over the 14 years of our sample. We map TFP in the distribution sector to our model parameter A_D and simulate the effects of a 51% increase in A_D. The results from this counterfactual are shown in Table 3. The table presents the counterfactual change in the aggregate distribution share, the elasticity of distribution costs with respect to employment, median employment in manufacturing, average employment in manufacturing and manufacturing TFP. We conduct the counterfactuals for two versions of the model: our baseline calibrated model and our model with ϵ set to 0.[29] Our main result is that median and average employment increase considerably more in response to an increase in A_D when $\epsilon > 0$. In our baseline calibration we find that median manufacturing employment increases by 5.2% in response to the increase in A_D, compared to a 1.8% increase when $\epsilon = 0$. Interestingly, the welfare change from the increase in A_D is not very sensitive to the value of ϵ. The first-order welfare gain from an increase in A_D comes from the highest quality plants expanding their sales in existing markets. ϵ plays a more important role in determining whether low quality plants stay active, affecting the left tail of the plant size distribution. However it plays a less important role for the right tail, and therefore only has second order effects on welfare.

[29]The counterfactual results in the $\epsilon = 0$ case capture the mechanisms in Melitz (2003).

Table 3: Counterfactual Results

	Data	Baseline	$\varepsilon = 0$
A_D	+51%	+51%	+51%
Aggr. distr share	-35%	-31%	-35%
Elasticity of distr costs	≈ 0 %	+ 0.5%	-
Median Employment		+5.2%	+1.8%
Average Employment		+5.7%	+1.8%
Manufacturing TFP (Welfare)		+1.80%	+1.79%

5. Conclusion and Future Work

What is the impact of productivity improvements in the distribution sectors of an economy on manufacturing productivity and the size distribution of manufacturing plants? In this paper we document that larger Indian manufacturing plants spend a larger share of their sales on distributing their products. To match this empirical finding we build a two-sector general equilibrium model in which firms and consumers are located around a circle. An important prediction from our model is that increases in the productivity of the distribution sector lead to increases in manufacturing productivity and average plant size. We calibrate the model to Indian macro and micro data, and find that the 50% increase in the productivity of the Indian distribution sector between 1995 and 2009 led to a 1.8% increase in manufacturing TFP and a 5.2% increase in median manufacturing plant size.

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6. Data Appendix

The Indian plant-level dataset used is the Indian Annual Survey of Industries (ASI) for the years 1985 to 2011. This can be purchased through India's Ministry of Statistics and Programme Implementation (MOSPI).[30]. The reference period of the survey is the accounting year, which in India begins on the 1st of April and ends on the 31st of March the following year. We reference the surveys by the earlier of the two years covered.[31] The ASI is a representative sample of plants with at least 10 workers, (20 workers for plants that don't use power). Sampling weights are provided with the data, and the sampling methodology in each year is described in more detail in Table 4.

We construct labor as the average number of personnel in the plant over the year.[32] We construct labor costs as total payments to labor over the course of the year. These payments include wages and salaries, bonuses, contributions to old-age pension funds (and other funds), and all welfare expenses.[33] Capital is constructed as the average of the opening and closing book value of fixed assets (net of depreciation). We construct intermediates as the sum of the value of materials consumed, fuels consumed and other intermediate expenses.[34] We construct gross output as the gross value of products sold plus all other sources of revenue. The gross value of products sold includes distribution expenses, as well as taxes and subsidies.[35]

[30] See the following link: http://mospi.nic.in/mospi_new/upload/asi/ASI_main.htm

[31] We refer to the ASI covering the accounting year 1996-1997 as the 1996 ASI.

[32] Personnel include wage or salary workers, supervisory/managerial staff, administrative/custodial employees and all unpaid workers (including family members).

[33] Included in these costs are social security charges such as employees' state insurance, compensation for work injuries, occupational diseases, maternity benefits, retrenchment and lay-off benefits. Also included are group benefits like direct expenditure on maternity, creches, canteen facilities, educational, cultural and recreational facilities, grants to trade unions, and co-operative stores meant for employees.

[34] Other intermediate expenses include repair and maintenance costs (plant/machinery, building, etc...), costs of contract and commission work, operating expenses (freight and transportation charges, taxes paid), non-operating expenses (communication, accounting, advertising), and insurance charges.

[35] Other sources of revenue include the value of electricity sold, the value of own construction, the value of resales, the value of additions to the stock of (semi-)finished goods, as well as receipts from services rendered (e.g. contract or commission work).

Table 4: Changes in ASI Sampling Methodology

Period	Census Sector	Sample Sector
1985-1986	12 less industrially developed states, 50 or more workers with power, 100 or more workers without power, industries with fewer than 50 plants in all of India, electricity sector	Stratified within state $\times$ 3-digit industry (NIC-70), 50% samples of remaining non-Census plants in alternate years
1987-1996	12 less industrially developed states, 100 or more workers (with or without power), all joint returns, all plants within state $\times$ 4-digit industry if $<$ 4 plants, all plants within state $\times$ 3-digit industry if $<$ 20 plants, electricity sector	Stratified within state $\times$ 3-digit industry (NIC-87), minimum sample of 20 plants within strata, otherwise 1/3 of plants sampled
1997	12 less industrially developed states, plants with $>$ 200 workers, 'significant units' with $<$ 200 workers but contributed highly to value of output between 1993-1995, public sector undertakings, electricity sector	Stratified within state $\times$ 3-digit industry (NIC-87), minimum of 4 plants sampled per stratum
1998	Complete enumeration states, plants with $>$ 200 workers, all joint returns, electricity sector omitted	Stratified within state $\times$ 4-digit industry (NIC-98), minimum of 8 plants per stratum
1999-2003	Complete enumeration states, plants with $\geq$ 100 or more workers, all joint returns	Stratified within state $\times$ 4-digit industry (NIC-98), minimum of 8 plants per stratum, exceptions:
2004-2006	6 less industrially developed states, 100 or more workers, all joint returns, all plants within state $\times$ 4-digit industry with $<$ 4 units	Stratified within state $\times$ 4-digit industry, 20% sampling, minimum of 4 plants
2007	5 less industrially developed states, 100 or more workers, all joint returns, all plants within state $\times$ 4-digit industry with $<$ 6 units	Stratified within state $\times$ 4-digit industry, minimum 6 plants, 12% sampling fraction: exceptions
2008-2011	6 less industrially developed states, 100 or more employees, all joint returns, all plants within state $\times$ 4-digit industry with $<$ 4 units	Stratified within district $\times$ 4-digit industry, minimum 4 plants, 20% sampling fraction

7. Empirical Appendix

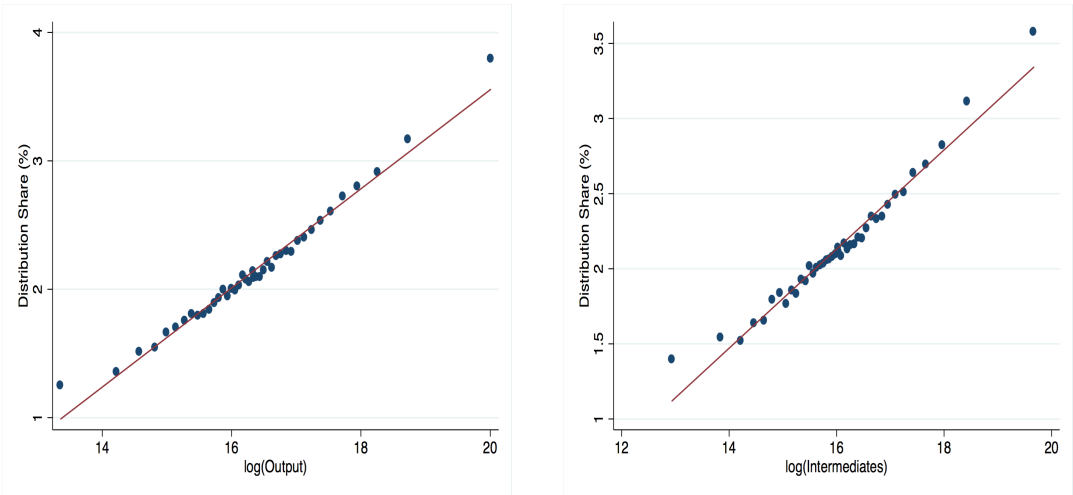

Figure 5: Binned Scatter Plot of Distribution Share Against Log(Plant Size)

Note: the figures on the left and right are binned scatter plot of plants' distribution shares against log(gross output) and log(intermediates) respectively. 50 equally sized bins are used. The line of best fit is shown in red. The ASI survey years used are 1993-2007. Both the distribution share and the measure of log(size) are residualized on full set of industry×year×district fixed effects. We use the most detailed industry classifications available in each year, 4-digit NIC87, 5-digit NIC98 and 5-digit NIC04. There are between 400 and 700 manufacturing industries at this level of disaggregation. In 2001 there were 593 districts in India, though the number has changed over time.

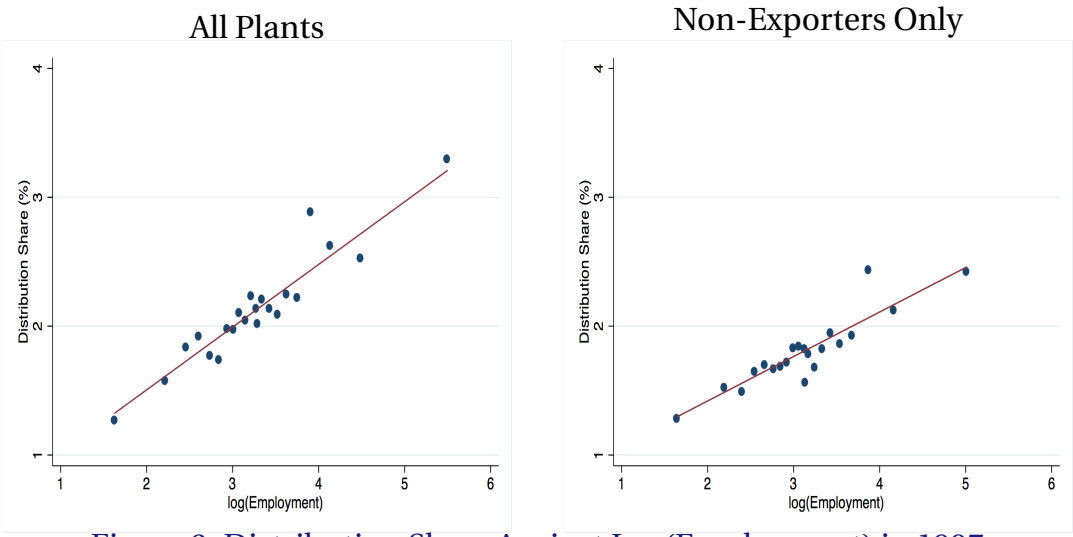

Figure 6: Distribution Share Against Log(Employment) in 1997

Note: the figures are binned scatter plot of plants' distribution shares against log(employment). 30 equally sized bins are used. The line of best fit is shown in red. Only the 1997 ASI survey year is used, as it is the only year in which plants reported the value of their exports. Both the distribution share and the measure of log(size) are residualized on full set of industry×district fixed effects. The industry classification used is 4-digit NIC87.

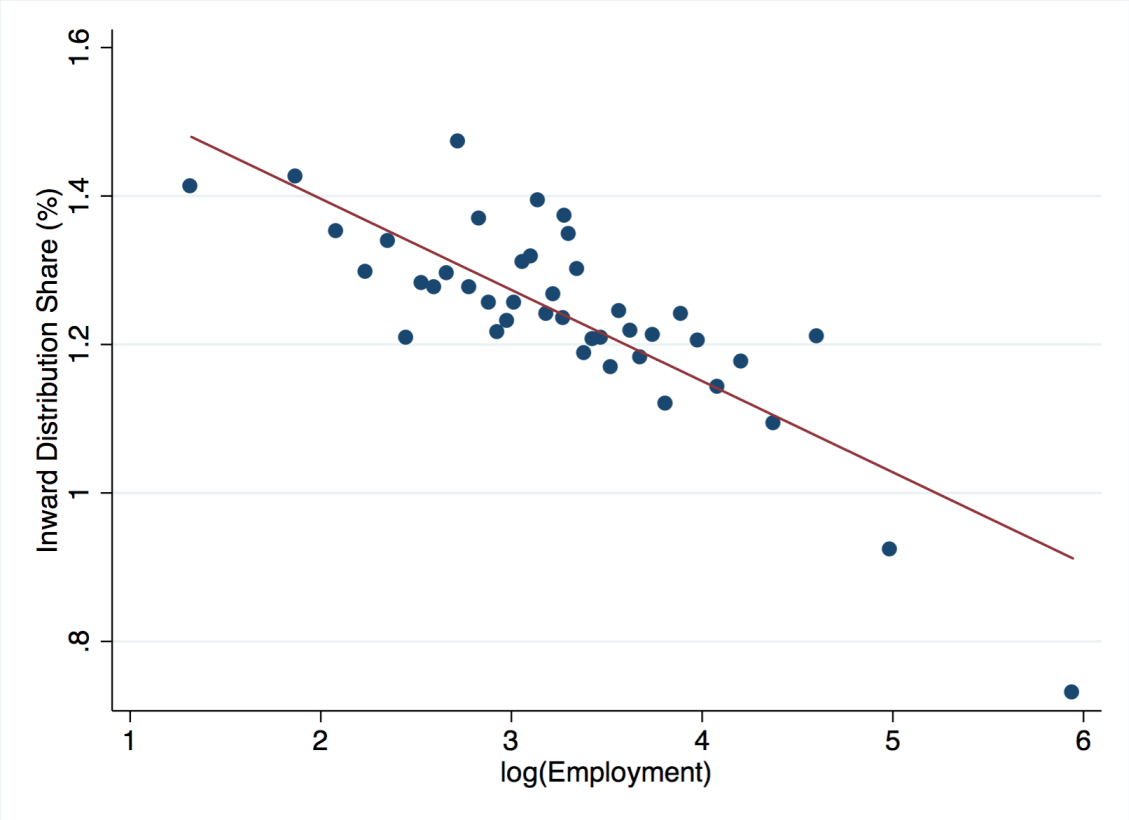

Figure 7: Inward Distribution Share Against Log(Employment)

Note: the figure is a binned scatter plot of plants' inward distribution shares against log(employment). 50 equally sized bins are used. The line of best fit is shown in red. The ASI survey years used are 1993, 1994 and 1996 as these are the only years in which inward distribution costs are reported. Both the inward distribution share and log(employment) are residualized on full set of industry×year×district fixed effects. The industry classification used is 4-digit NIC87.

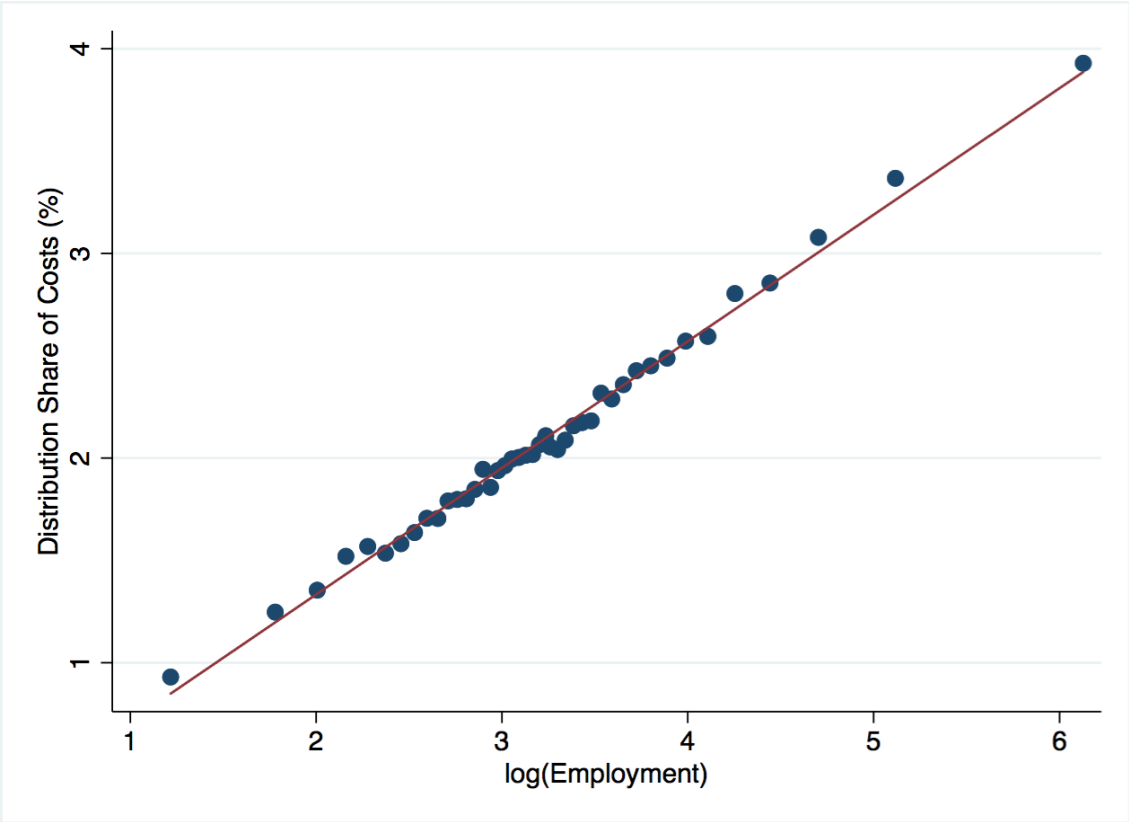

Figure 8: Distribution Share of Total Costs Against Log(Employment)

Note: the figure is a binned scatter plot of plants' outward distribution expenses as a share of total variable cost against log(employment). 50 equally sized bins are used. The line of best fit is shown in red. Both the distribution share of costs and log(employment) are residualized on full set of industry×year×district fixed effects. The industry classification used is 4-digit NIC87.

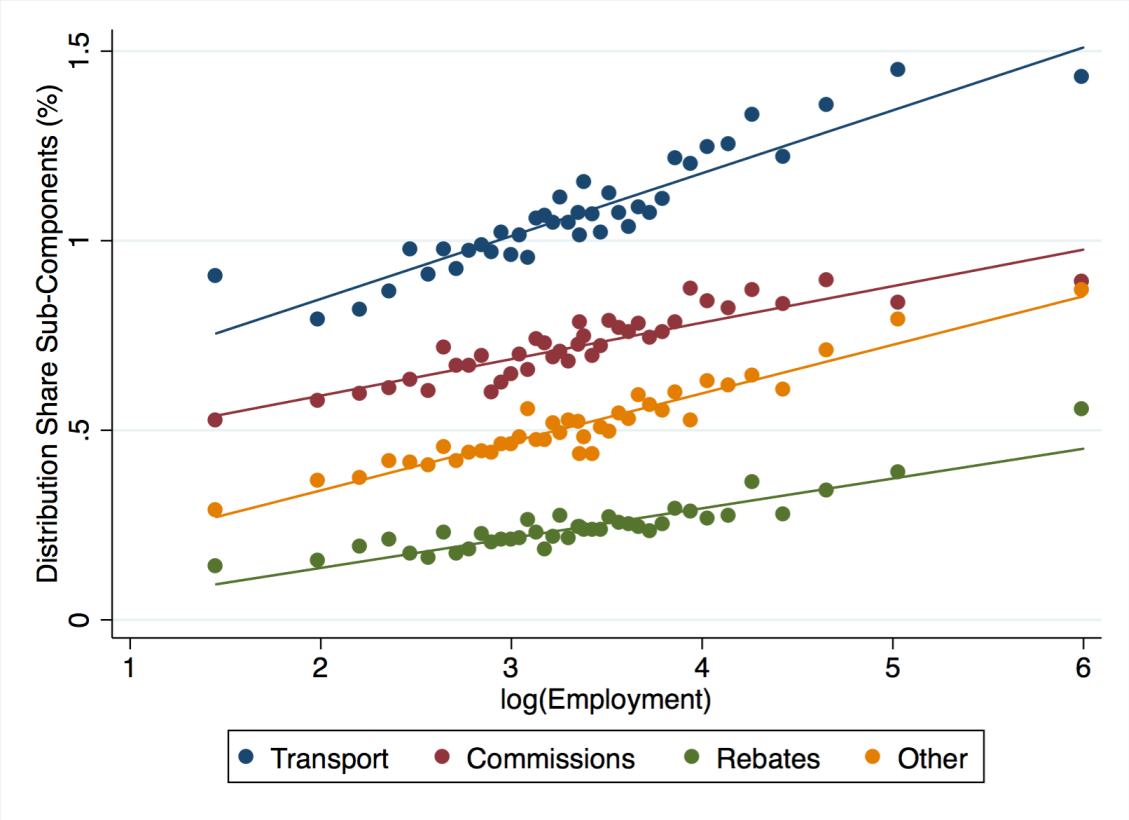

Figure 9: Distribution Share Sub-Components Against Log(Employment)

Note: the figure is a binned scatter plot of plants' distribution shares against log(employment). 50 equally sized bins are used. The line of best fit is shown in red. The ASI survey years used are 1993, 1994 and 1996 as these are the only years in which inward distribution costs are reported. Both the inward distribution share and log(employment) are residualized on full set of industry×year×district fixed effects. The industry classification used is 4-digit NIC87.