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THE DEATHS OF MANUFACTURING PLANTS

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ABSTRACT

This paper examines the causes of manufacturing plant deaths within and across industries in the U.S. from 1977-1997. The effects of international competition from low wage countries, exporting, ownership structure, product diversity, productivity, geography, and plant characteristics are considered. The probability of shutdowns is higher in industries that face increased competition from low-income countries, especially for low-wage, labor-intensive plants within those industries. Conditional on industry and plant characteristics, closures occur more often at plants that are part of a multi-plant firm and at plants that have recently experienced a change in ownership. Plants owned by U.S. multinationals are more likely to close than similar plants at non-multinational firms. Exits occur less frequently at multi-product plants, at exporters, at plants that pay above average wages, and at large, older, more productive and more capital-intensive plants.

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1. Introduction

Plant shutdowns are an integral part of the process of industrial restructuring. Plant deaths shape industry and aggregate productivity paths and are a major component of job destruction. Over a typical five year period, more than 32% of U.S. manufacturing plants shut down, accounting for more than 22% of total job destruction.[1] Foster et al. (1998) find that plant births and deaths "contribute disproportionately to industry productivity growth", as much as 35% of average annual multi-factor productivity growth. While plant deaths are part of the normal process of the entry and exit of firms, there is substantial heterogeneity in the shutdown probability across plants, firms and industries. Some plant shutdowns are associated with firm failure, others are choices by firms to reallocate activity among production units and some plants are driven out of existence by increasing foreign competition. This paper examines the role of plant, firm, and industry characteristics in the shutdown process as well as the effect of increasing import shares from low wage countries.

The determinants of plant deaths have been an active area of empirical and theoretical research. Dunne, Roberts, and Samuelson (1988, 1989), using data on the entire U.S. manufacturing sector, established the strong co-movement of industry exit and entry rates as well as the relationship between survival and plant age and size. Their work emphasized the importance of sunk entry costs in determining death rates as well as the large degree of heterogeneity across plants within industries.

Theoretical work has resulted in a number of models of industries with heterogeneous firms in part designed to match the stylized facts of the empirical literature.[2] These papers have emphasized the importance of understanding the shutdown decision in modeling the dynamics of industry and aggregate productivity. However, to maintain analytical tractability, these models have typically assumed a reduced number of state variables for the firm, notably productivity and the capital stock. Associated empirical work has typically focused less on the shutdown margin than on the differences in estimated industry productivity under the assumptions

[1] Data tabulated by the authors from the Longitudinal Research Database of the Bureau of the Census.

[2] See Jovanovic (1982), Hopenhayn (1992a,b), Ericson and Pakes (1995), Olley and Pakes (1996) and Melitz (1999).

of firm heterogeneity. In this paper, we concentrate exclusively on the manufacturing firm's decision to close a plant. In doing so, we develop a new, richer portrait of the shutdown decision.

Our empirical work focuses on four important aspects of plant deaths which have been largely ignored in the previous literature. We provide the first evidence on the effect of imports from low wage countries on the survival of domestic plants.[3] Second, we examine the role of firm structure and ownership in the shutdown decision. Third, we consider product market characteristics including whether the plant sells some of its output abroad and whether the plant produces multiple products. Finally, we extend the range of plant attributes that might influence the probability of failure to include variation in inputs such as capital and skill. We also provide a new measure of the sunk costs of entry based on entry and exit rates. Throughout, we distinguish between unconditional and conditional relationships and control for sunk costs of entry and regional agglomeration.

Each of our four areas of focus provides important new insights into the plant shutdown decision. We provide the first evidence on the role of imports from low wage countries on plant survival. We use new industry-specific measures on the share of imports from low wage countries and find that such import penetration sharply increases the probability of plant death. More importantly, low wage import competition interacts with plant characteristics within industries in ways predicted by endowment-based trade theory. The least skill and capital intensive plants have the greatest increase in their shutdown probabilities when low wage countries enter their markets. This relationship suggests that imports from low wage countries contribute to the reallocation of activity towards the most capital-intensive, highest wage plants in the manufacturing sector.

The nature of the firm plays a crucial role in plant shutdowns. Unconditionally, multi-plant firms are far less likely to shut down a plant than a single-plant firm. However, this positive relationship is driven entirely by the nature of the plants within a multi-unit firm. Multi-unit firms have plants with better characteristics, i.e. they are older, bigger, more productive, capital-intensive etc. However, accounting for other plant attributes, these same firms are actually *more* likely to close a plant. Similarly, plants

[3] We recognize the interest in all forms of import competition but in this paper we choose to focus on only one aspect of changing US trade patterns over the last 30 years.

that have changed ownership have positive attributes that make them less likely to die. However, conditioning on the plant's qualities, the new owner is significantly more likely to close the acquisition. The multinational status of the firm also influences its decisions to close plants. We find that a U.S. multinational is more likely to close a plant than a comparable domestic firm.

Third, the characteristics of plant product markets are strongly associated with the likelihood of exit. Single-product plants are much more likely to fail in any five year period than establishments producing multiple goods. The probability of failure continues to decrease as the number of products made at the plant rises, even controlling for other plant attributes. Exporting plants are also significantly less likely to die. The export status of the plant reduces the probability of shutdown by as much as 15% even after accounting for plant size, productivity, factor intensity and ownership structure.

Finally, while plant size, age and productivity are important determinants of plant survival, there are additional positive effects of capital and skill intensity at the plant. Within and across industries, survival probabilities are greater for plants with high capital-labor ratios and those with relatively skilled, high wage workers. In particular, these plants are better able to survive increases in imports from low wage countries.

The remainder of the paper is organized as follows. The next section begins with a simple empirical model of plant shutdowns followed by the development of a number of hypotheses about the determinants of plant deaths. Section 3 introduces the new import competition measures. In Section 4, we give a brief overview of the plant and firm data, describe the particular variables we employ in the empirical analysis, and document their unconditional relationship to plant shutdowns. Section 5 presents the main results on plant death from our multivariate empirical specification. Section 6 concludes.

2. An empirical model of plant shutdowns

This paper examines the incumbent firm's decision to close a plant. For single-plant firms this is equivalent to going out of business while for multi-plant firms this decision may represent a discrete adjustment to ongoing capacity. We present an empirical model of the shutdown decision which is compatible with a wide range of existing models of heterogeneous firm dynamics. We also assemble predictions about plant deaths from a variety of fields including international trade, economic geography, and industrial organization. Building on the existing literature, we incorporate plant characteristics such as age, size, and productivity as determinants of exit while also considering the differential use of capital and skilled labor by plants within industries. Our two major contributions come from the extensive information on the role of firms in the plant shutdown decision and the ability to identify industries facing increased competition from international trade. The interaction of plant production techniques and low wage imports plays a significant role in the probability of plant death.

In this section we start by presenting a simple empirical model of the shutdown decision. The model is general enough to be consistent with the implications of a large number of theoretical models in the growing literature on industry dynamics with heterogeneous firms. At every point in time the incumbent firm maximizes the expected present value of net cash flows. In any period, the firm first decides whether to continue operating or exit the industry. Conditional on remaining in business, the firm then decides on the appropriate level(s) of investment.[4] The net cash flows in any period are determined by conditions outside the industry, characteristics (or state variables) of the firm, and state variables for the plant itself. The three vectors of state variables are given by $(\theta_t, \lambda_t, \gamma_t)$ where θ_t is the set of exogenous factors reflecting conditions outside the domestic industry, λ_t is a vector of firm state variables, and γ_t summarizes the market structure of the domestic industry including the plant's own prior investment history. Single period net cash flow net of investment costs is given by

$$R_t\left(\theta_t, \lambda_t, \gamma_t, i_t\right) = \pi_t\left(\theta_t, \lambda_t, \gamma_t\right) - c(i_t). \tag{1}$$

The firm's problem for each plant can be described by the general value function for the dynamic program,

$$\Pi_t\left(\theta_t, \lambda_t\right) = \max\left(L, \sup R_t\left(\theta_t, \lambda_t, \gamma_t, i_t\right) + \beta\Pi_{t+1}\left(\theta_{t+1}, \lambda_{t+1}, \gamma_{t+1}|\Omega_t\right)\right) \tag{2}$$

[4] In our empirical work, we will consider both physical and human capital to be relevant for the shutdown decision.

where L is the liquidation value of the plant, R_t is current period net cash flows, i_t is a vector of current period investment in various types of capital and Ω_t is the current information available to the firm. Only if the ongoing value of the enterprise is greater than the liquidation value does the firm then choose a non-negative level of investment for the plant. We define the indicator variable D to be equal to 1 if the firm exits. Then the shutdown decision is written as

$$D_t = \begin{matrix} 1 \text{ if } d_t < \underline{d}_t\left(\theta_t, \lambda_t, \gamma_t\right) \\ 0 \qquad \text{otherwise} \end{matrix} \tag{3}$$

In this paper, we focus exclusively on the shutdown decision and estimate a non-structural version of equation 3 as a function of a set of industry, firm and plant characteristics. In the following sections we identify plant, firm and industry variables from a variety of literatures that may affect the firm's decision to close a plant or stop operating entirely.

2.1. Heterogeneous firms and industry equilibrium

There is a growing body of research on plant entry and exit stimulated by the work of Dunne, Roberts, and Samuelson (1988, 1989). Looking across industries, Dunne, Roberts and Samuelson (henceforth DRS) (1988) find that plant entry and exit rates are strongly positively correlated, and that the correlation persists over time. In DRS (1989), they consider the role of plant size, age, and ownership type as determinants of plant failure. They find that failure rates decline as size and age increase.

In his influential papers, Hopenhayn (1992a,b) develops a general equilibrium model of entry and exit to largely match the DRS facts. Hopenhayn's model focuses on a steady state with balanced entry and exit. Comparative static exercises reveal that increases in sunk entry costs lower both entry and exit rates causing them to move together. In addition, the models have the characteristics that failure rates are decreasing in both size and age of the firm, matching the within-industry facts offered by DRS (1989).

Hypothesis 1 *The probability of plant death is decreasing in industry sunk costs of entry.*

Hypothesis 2 *The probability of plant death is decreasing in plant size.*

Hypothesis 3 *The probability of plant death is decreasing in plant age.*

These features of correlated entry and exit and the negative relation between exit and plant size and age are also present in the heterogeneous firm models of Jovanovic (1982), Ericson and Pakes (1995), Olley and Pakes (1996) and Melitz (2002). All these market structure models are driven by the interaction of idiosyncratic paths for plant productivity with sunk costs of entry. If productivity falls far enough, plants exit the industry. As a result, all the models predict that low productivity plants are unconditionally more likely to exit. In addition, the evolution of industry structure in these models means that younger plants are also much more likely to fail. If the stock of physical capital can affect the distribution of future plant productivity, as in Olley and Pakes (1996), then low capital intensity plants will be more likely to exit.

Hypothesis 4 *The probability of plant death is decreasing in plant productivity.*

Hypothesis 5 *The probability of plant death is decreasing in plant physical capital intensity.*

We also consider the possibility that the stock of human capital matters for plant productivity and include a variety of proxies in our empirical work.

Hypothesis 6 *The probability of plant death is decreasing in plant skill intensity.*

2.2. International Trade and Exit

One of the primary contributions of the current paper is to examine the impact of increased foreign competition on the shutdown decision. Several papers have integrated trade into an industry model with heterogeneous plants with direct implications for exit. Melitz (2002) adds imperfect competition and exporting with sunk costs of entry to the Hopenhayn (1992a) model. He finds that exposure to international trade will induce only the more productive firms to enter the export market and simultaneously causes the least productive firms to exit the domestic market entirely. Continued increases in the industry's exposure to trade through reduced trade costs or larger numbers of trading partners will further push out the low end firms and may cause the most productive firms to expand. To the extent that exporting signals positive information about the plant, beyond measured productivity, we would expect current period exporters to have a lower probability of failure.

In related work, Bernard, Eaton, Jensen, and Kortum (2000) (henceforth BEJK) develop a static Ricardian model of exporting where again only the most productive domestic firms are able to overcome the additional costs of international trade and thus export. In this model, a reduction in trade costs leads to increases in both imports and exports. The cost reduction has two main effects. Some plants that were producing just for the domestic market no longer are the low price producers and must shut down. These plants are typically of lower than average efficiency. In addition, some plants that were exporting are no longer the low cost supplier in the foreign market and cease exporting. These former exporters may or may not continue to supply the domestic market but their shutdown rates will be lower than those for domestic-only suppliers. In addition, some high productivity firms now start exporting. The model predicts that trade cost reductions, or increased trading partners will lead to increased plant closure and the probability of closure will be highest among the least productive plants and lower among current exporters. If export sales do not covary perfectly with domestic sales, then the resulting reduction in the variance of sales and profits would increase the probability of survival.

Hypothesis 7 *The probability of plant death is increasing in foreign competition.*

Hypothesis 8 *The probability of plant death is lower for exporters.*

Both theoretical models contain two relevant predictions for our empirical work. First, increased trade will raise the exit rate in exposed industries. Second, the probability of shutdown will increase the most among plants with the lowest comparative advantage. One necessary limitation of the models is that both consider only aggregate plant productivity as a determinant of comparative advantage. We extend the factors contributing to a plant's comparative advantage to include measures of production techniques such as skill and capital intensity. In the face of increased import competition, we expect that plants with low productivity and/or low skill intensity and/or low capital intensity would be the most likely to fail. In our empirical work, we look for a negative relationship between the interaction of low wage competition and these plant attributes

> **Hypothesis 9** *The probability of plant death is increasing in the interaction of foreign competition and low physical capital intensity/low skill intensity/low productivity.*

Firm heterogeneity is not essential to establishing the link between import competition and plant death. Albequerque and Rebelo (2000) model a two sector economy with homogeneous firms and sunk costs of entry. Trade liberalization may induce reallocation across the sectors, through firm deaths, if the import-competing industry is close to zero profits before sunk costs and the export-competing industry is at zero profits net of sunk costs. In such a case, resources will move from the import-competing sector to the exporting sector and the transition will be associated with exit in the former and entry in the latter.

2.3. Product Markets

If there are sunk costs of entry into new product markets analogous to the sunk costs of entry into exporting or the domestic market, we should expect to see a lower probability of death among plants that produce multiple products. Alternatively, the production of differing products may reduce the variability of sales and profits and thus increased expected survival.

> **Hypothesis 10** *The probability of plant death is decreasing in the number of products produced.*

2.4. Firm Structure

A different strand of the existing literature on plant closures considers exit from declining industries. Typically in such studies the focus is on the pattern of plant closure within an industry with the 'decline' of the industry taken as exogenous. Ghemawat and Nalebuff (1985) show that in a duopoly with Cournot competition, equal costs and declining demand, the largest firms exits first as the smaller producer will be a successful monopolist for longer. Allowing for cost advantages for large firms can overturn the theoretical results if the cost differentials are substantial enough. Whinston (1988) shows that the single plant assumption is important for the results on size and exit and argues that plants in multi-plant firms may be more likely to exit. Dunne, Roberts, and Samuelson (1989) find that plants that are part of multi-unit firms have lower failure rates than single-plant firms, even controlling for size and age.

The results from the related empirical literature are mixed, although all studies find that larger plants are less likely to exit. Lieberman (1990) and Baden-Fuller (1989) find that diversified firms are more likely to close plants, although Deily (1991) finds no such effect in the steel industry. Gibson and Harris (1996) look specifically at plant exit during a period of trade liberalization and quota reduction in New Zealand. They find that large, old, low cost establishments are more likely to survive the liberalization and diversified multi-plant firms were more likely to close plants.

Hypothesis 11 *The probability of plant death may be higher or lower for plants in multi-plant firms.*

Hypothesis 12 *The probability of plant death is higher for plants in diversified firms.*

We also consider the role of takeovers, or ownership changes, in plant survival. A recently acquired plant may be more or less likely to survive than a comparable plant without an ownership change. Survival chances will be lower if the acquisition is a bad match for the new firm or if the ownership change was intended to allow the firm to reduce overall capacity in the industry. Survival will be enhanced if the new plant-firm relationship is mutually beneficial.

Hypothesis 13 *The probability of plant death may be higher or lower for plants with recent ownership changes.*

Finally among the firm characteristics, we examine the role of US multinationals in plant closures. Multinational status may itself be an indicator of unobserved quality of the firm which would suggest a lower probability of closure for its plants. Doms and Jensen (1998) find that multinational plants have superior observable characteristics. However, Brainard and Riker (1997a,b) and Braconier and Ekholm (2000) find that multinationals have an increased elasticity of labor demand due to their ability to shift production across locations within the firm. They do not examine whether this activity also coincides with increased shutdown of domestic plants. This ability to relocate production within the firm may lead to an increased probability of shutdown.

Hypothesis 14 *The probability of plant death may be higher or lower for plants owned by multinationals.*

2.5. Geography and agglomeration

Recent work in economic geography has emphasized the importance of regional industrial structure for the survival and death of plants. Duranton and Puga (2000) establish a collection of stylized facts about city structure and sectoral composition. Summarizing their own research and that of others, especially Dumais, Ellison and Glaeser (2002), they report that the birth and death processes are spatially biased. Plant deaths are above average in diverse cities while plant closure is lower in concentrated regions. We create measures of relative regional specialization and relative regional diversity to control for geographic factors in plant shutdowns.

Hypothesis 15 *The probability of plant death is higher in industrial diverse regions.*

Hypothesis 16 *The probability of plant death is lower in industrially concentrated regions.*

While this list of hypotheses is by no means exhaustive, it allows us to consider the unconditional and conditional effects of a wide variety of factors that affect the plant shutdown decision.

3. Imports from Low Wage Countries

One contribution of this paper is the analysis of the effects of imports from low wage countries on the shutdown decision. By focusing on the role of low wage countries, we concentrate on the fastest growing component of U.S. imports over the last 25 years. We make use of two new measures of international import shares developed by Schott (2002) from product level import data collected by the Bureau of the Census. The first measure, $valueshr_i$, is the share of the value of imports coming from low wage countries in industry i,

$$valueshr_i = \frac{\text{imports from low wage countries}_i}{\text{total value of imports}_i}.$$

This measure is relatively straightforward as it considers the fraction of the value of imports coming from countries with income per capita below a predetermined cutoff.

The second measure, $prodshr_i$, is the count of products within industry i coming from those same low wage countries relative to the total count of products imported in industry i,

$$prodshr_i = \frac{\text{products imported from low wage countries}_i}{\text{total \# of products imported}_i}.$$

A product is defined to be a ten digit HS category. A product is considered to be imported from a low wage country if any low wage country has positive imports in the HS category during the calendar year. Both measures are indicators of the distribution of activity in imports coming from low wage countries rather than measures of the level of activity in a particular sectors. We define 'low wage' to be those countries that have per capita GDP levels less than 5% of that of the U.S. (see the list of countries in the appendix).[5] The 5% cutoff was chosen because it captured a large part of the change in U.S. imports over the period combined with the fact that the country set was relatively stable during the sample.[6] For our empirical work, we use an annual average of the measures by industry over the 5 prior years.

The measures we employ in this paper have both advantages and disadvantages relative to existing measures. One distinct advantage is these

[5] We use current real exchange rates to perform the conversion to US$ rather than a PPP exchange rate. For such low levels of income the use of current rates does not change the list of countries below the cutoff, while the data availability on PPP exchange rates sharply limits the available number of countries and years.

[6] For countries with per capita income levels at or below 30% of the U.S. this group experienced by far the largest increase in import share over the relevant 20 year period.

measures are largely robust to events that affect both the domestic industry and competing imports. In addition, we have both measures of value and the range of the product space within an industry where competition is occurring. An obvious disadvantage is that the measures only capture the changing share of a subgroup of countries. However, given the focus in recent years on competition from China and other low income countries, this provides us with a clean picture of the importance of these imports as opposed to imports from advanced economies.

Existing measures of international competition have a variety of potential problems. A standard index of industry import penetration,

$$\frac{\text{imports}}{\text{domestic production} + \text{imports}},$$

suffers from the fact that domestic output of the industry is in the denominator, potentially leading to a spurious positive correlation with plant failure. Industry import price measures, arguably a preferable indicator of pressure from international trade, are rarely available for a wide range of industries or time periods.[7] In addition, the heterogeneity of products within most manufacturing industries may weaken the relationship between aggregate industry prices and domestic outcomes.

Figure 1 shows our two low wage import measures for each of our 5 year periods.[8] During 1972-76, industries show a wide range of low wage imports as measured by the product import share. The median industry sees imports from low wage countries in 38% of its products. In contrast, for the same period, few industries have a large value share of imports from low wage countries. Low wage countries contribute only 0.3% of the total value of imports for the median industry.

Over time, both measures of low wage import shares have increased substantially. In Figure 1, this is seen by an upward and rightward shift of the scatter. By 1987-1991, the share of products with any imports from a low wage country had risen to 62%. Most of the increase in product penetration occurred in the latter part of the sample with over half coming during 1982-1986. Similarly, the measure of value penetration coming from

[7] For the US, import price series are available only after 1977, and only for more aggregate 3-digit SIC industries.

[8] Note that the competition measures are annual averages for the five year periods preceding the Census year, i.e. 1972-76, 1977-81, 1982-86, and 1987-1991.

this group of poor countries increased for the median industry from 0.3% to 2.5%. Over two thirds of that increase occurred during the 1980s. Generally, across industries, high levels of product penetration are positively correlated with subsequent increases in the share of import value coming from poor countries.

4. Data

The data in this paper come from two sources. In addition to the competition measures described above, the plant and firm data come from the Longitudinal Research Database (LRD) of the Bureau of the Census. We use data from the Censuses of Manufactures (CM) starting in 1977 and conducted every fifth year through 1997. The sampling unit for the Census is a manufacturing establishment, or plant, and the sampling frame in each Census year includes detailed information on inputs, output, and ownership on all establishments.[9]

From the Census, we obtain plant characteristics including location, capital stock at the plant, the quantity of and wages paid to non-production and production workers, total value of shipments, total value of exports, energy and purchased material inputs, the number of products produced at the plant, the primary Standard Industrial Classification (SIC), and age. We also can match plants to their parent firms and obtain information on the number of plants in the firm, the share of total firm assets held overseas, and changes in ownership.

To develop our sample of plants we must make several modifications to the basic data in the LRD. First, we drop any industry whose products are categorized as 'not elsewhere classified'. These 'industries' are typically catch-all categories for a group of heterogenous products. In practice, this corresponds to any industry whose four digit SIC code ends in '9'. Second, we must aggregate some 4-digit SIC industries in order to match the import competition measures.[10] This aggregation leaves us with 337 industry

[9] While the LRD does contain basic information on small plants (so-called Administrative records), we do not include them in this study due to the lack of information on inputs other than total employees. Since our competition measures start only in 1972, we must start our sample with the 1977 Census.

[10] This aggregation is necessary because the HS categories in the customs forms cannot distinguish between certain products which normally would fall into distinct 4-digit SIC

categories. We use information on all manufacturing establishments in the 1977, 1982, 1987, and 1992 Censuses but must drop any establishment that does not report one of the input or output measures.[11] We are left with 450,000+ plant-year observations across the four panels.

4.1. Variables

In this section we describe the construction of the variables used to test the range of hypotheses from Section 2.. We also report the unconditional relationship between the variables and the probability of plant death. Table 1 reports the mean of each variable for two types of plants, deaths and survivors. Column 3 of Table 1 also gives the marginal effect on the probability of plant shutdown from a univariate probit of plant death of the form:

$$Pr\left(D_{pt} = 1 | X_{pt}\right) = \Phi\left(c_t + \beta X_{pt}\right) \tag{4}$$

where X_{pt} is the plant characteristic in year t and c_t is a full set of year dummies. Standard errors are robust to repeated observations on individual plants. Column 1 of Table 7 provides a summary of both the univariate probit results as well as the full multivariate specification.

4.1.1. Imports from Low Wage Countries

Starting with the role of low wage imports in plant deaths, we find that failing plants are in industries with higher import shares from low wage countries. Including both share measures as well as their interaction, we find a strong positive relationship to the probability of death. This is best seen in Figure 2 and Table 2.

From the unconditional probit including low wage import shares and their interaction, we calculate for each industry and year the probability of failure.[12] We then subtract off the probability calculated for an industry with median levels of low wage import shares in that year. The resulting

categories.

[11] For 1977 and 1982 we use the Bureau of the Census imputations of capital stock for establishments not included in the Annual Survey of Manufactures. Our results are robust to the exclusion of these plants.

[12] Since the competition levels are available only at the industry level, each plant in an industry has the same calculated probability of failure.

number is the increase (decrease) in the probability of death as import shares rise above (fall below) that in the median industry. Figure 2 plots the relationship between import shares levels and the unconditional probability of failure over the relevant range of the import variables. Clearly, higher shares of imports and products from low wage countries are associated with large increases in the probability of plant failure.

Table 2 shows the distribution of these industry effects for 1977 and 1992. In 1977, most industries had only modest exposure to low wage imports. Even so, 14% of the industries faced enough imports from low wage countries to raise the unconditional probability of plant death by at least 2.5 percentage points above that of a plant facing median levels.[13] Sixteen industries, including Leather Gloves (SIC3151) and Women's Dresses (SIC2335), faced enough low wage competition that their probability of plant shutdown was more than 7.5 percentage points above the median.

By 1992, many more industries were facing substantial imports from low wage countries as shown by the increase in the extremes of the table. The probability of plant death was raised by at least 2.5 percentage points in 27% of industries, and more than 9% of the industries saw their failure probabilities rise by 12.5 or more percentage points. Overall there is a strong positive relationship between the unconditional probability of plant death and the level of imports from low wage countries.[14]

4.1.2. Ownership Structure

The variables on firm ownership structure are all categorical in nature and come from the LRD. We consider several possible configurations of multi-plant firms. A plant is said to belong to a multi-plant firm if there is at least one other plant with the same firm ownership number,

$$multi = \begin{matrix} 1 \\ 0 \end{matrix} \begin{cases} \text{if } \exists \text{ at least one other plant with the same FirmID} \\ \text{otherwise} \end{cases}.$$

However, in our empirical work we would like to consider two types of plants within the multi-plant firm. The first, called '*orphan*', is a plant that has a unique industry identifier within the firm, i.e. there are no other plants

[13] The unconditional probability of death over all plants was 26.2%.

[14] We caution that nowhere in this paper do we consider plant entry. Our results do not provide information on net plant entry or exit.

with the same primary industry classification in the same firm. Plants of this type are unique within the context of a diversified firm.

$$orphan = \begin{matrix} 1 \\ 0 \end{matrix} \begin{cases} \text{if } multi = 1 \ \& \ \nexists \text{ a plant with the same SIC within the firm} \\ \text{otherwise} \end{cases}.$$

The second type of plant within the multi-plant firm, '*sibling*', shares a primary industry classification with at least one other plant within the firm.

$$sibling = \begin{matrix} 1 \\ 0 \end{matrix} \begin{cases} \text{if } multi = 1 \ \& \ orphan = 0 \\ \text{otherwise} \end{cases}.$$

Together orphans and siblings span the set of plants that belong to a multi-plant firm, i.e. $orphan + sibling = multi$.

On average, 34.1% of surviving plants belong to multi-plant firms as opposed to 27.6% of plants that exit (Table 1). Orphans are slightly more likely to be found among dying plants than continuing ones (7.0% versus 6.7%), while siblings are much more likely to be found among survivors (27.4% versus 20.6%). Unconditionally, belonging to a multi-plant firm is associated with a 3.6 percentage point reduction in the probability of death for the plant. This is a large reduction given that the overall probability of plant failure in the sample was 26.2%. Plants with either sibling or orphan status are less likely to shut down than stand alone establishments. The reduction in the probability of death is much larger for siblings (7.0 percentage points) than for orphans (1.0 percentage point).

A plant is said to have changed owners in the previous five years if the firm ID in the dataset changes,

$$takeover_t = \begin{matrix} 1 \\ 0 \end{matrix} \begin{cases} \text{if } FirmID_t \neq FirmID_{t-5} \\ \text{otherwise} \end{cases}.$$

For plants that did not exist in year t-5 we assume there was no change in ownership. This measure cannot distinguish between various types of ownership changes such as hostile versus friendly takeovers. 8.3% of plants labelled as 'takeovers' survived to the next Census, while only 7.3% of such plants died. The probability of closure was 2.9 percentage points lower for plants that experienced an ownership change in the previous five years than at plants without an ownership change.

The final firm characteristic we consider is its multinational status. We construct a measure of multinational status as a function of the share of firm assets held overseas. We define a U.S. multinational to be a firm with at least 10% of its assets held outside the United States,

$$USMNC = \begin{matrix} 1 \\ 0 \end{matrix} \left\{ \begin{matrix} \text{if } \frac{\text{Foreign Assets}}{\text{Total Assets}} \geq 0.1 \\ \text{otherwise} \end{matrix} \right. .$$

The assets measure is only available for U.S. firms so we cannot construct a measure of foreign multinational ownership in our sample.[15] This means that plants owned by foreign multinationals are grouped into the category that includes firms with no foreign presence. Plants owned by U.S. multinationals were more likely to be found among survivors (8.5% versus 6.2%) and unconditionally, these plants had a 6.2 percentage point reduction in their probability of death.

We caution that all these results on firm ownership are unconditional. In particular, plants that change owners, are part of larger firms and are part of multinational groups also have 'good' plant characteristics. Size, age, productivity, capital intensity and wages are all positively and significantly correlated with each of the firm measures. In Section 5., we control for plant attributes and attempt to identify the marginal effect of firm ownership structure on the probability of plant death.

4.1.3. Products and Markets

Recent models of heterogeneous plants and international trade by Melitz (2002) and BEJK (2000) predict that an exporting plant should have a lower probability of failure than a non-exporter. In these models, the relationship is driven by the relatively high productivity of exporting plants as opposed to exporting itself. We recognize that exporting may proxy for other unobservable, desirable characteristics of the plant. Our export measure is an indicator variable that is one when the plant exports and zero otherwise. As seen in Table 1, surviving plants are much more likely to be exporters (22.1%) than are failing plants (12.0%). The results from the unconditional probit show that exporting by the plant is associated with a 12.6 percentage point reduction in the probability of death. This magnitude is enormous given that the unconditional average probability of death is 26.2%.

[15] See Doms and Jensen (1998) for a description of this measure.

We also consider a measure of the market heterogeneity of the plant's output through the number of products that it reports manufacturing. If every new product requires additional sunk costs of entry, analogous to the export market, only the most productive plants will be able to enter multiple product markets. Survivors produce 3.5 products on average while deaths produce 2.6. For the probits, we create separate dummy variables for plants that produce 2, 3, or 4+ products.[16] The probability of death is decreasing in the number of products made by the plant. Relative to single product establishments, plants that produce 2, 3, or 4+ products have failure probabilities that are 5.7, 11.1 and 15.6 percentage points lower respectively.

4.1.4. Entry Costs

The industry market structure models discussed in Section 2. combine firm heterogeneity with sunk costs of entry. The magnitude of the sunk costs of entry is of primary importance in determining the steady state rate of firm births and deaths within the industry. Since our focus is not on the estimation of sunk entry costs and because entry costs may covary with, or be determined by, plant characteristics such as capital or skill intensity, we need to control for entry costs in our multivariate empirical specification. Unfortunately, there is no direct evidence on the magnitude of these costs across industries or over time. Most other cross-industry studies of shutdown have included industry fixed effects to soak up variation in industry entry costs. To the extent that sunk costs are varying across time as well as industries, fixed effects are inadequate.

Instead of a direct measure, we use the theory itself to generate an indirect measure. The market structure models all predict that, in steady state, entry and entry rates will covary exactly as sunk entry costs change. If all our industries were in steady state, we could use the industry entry rate to proxy for industry sunk costs in our plant shutdown equation.

In practice, of course, some industries are growing and others are declining leading to important differences in the two margins. However, we can still use the co-movement of the two rates across industries to develop an entry cost measure. Our measure of industry entry costs is based on the

[16] Single product plants account for 39% of the sample. Plants that produce 2, 3, or 4+ products account for 20%, 11%, and 30% respectively.

minimum of the entry and exit rates,

$$EC_i = -\{\min\left[\text{entryrate}_i, \text{exitrate}_i\right]\}.$$

Contracting industries by definition will have higher exit rates than entry rates. However, a contracting industry with low entry costs will have a higher entry rate. Conversely, an expanding industry with relatively low entry costs will have fewer plant deaths and a lower exit rate.[17]

The mean of our entry cost measure for deaths and survivors is given in Table 1. As expected, industry entry costs are significantly lower on average for plants that die, -0.35, that for plants that survive, -0.32. The marginal effect on the probability of death for the average plant is large, negative and significant.

4.1.5. Plant Performance

Both the existing theoretical literature and previous empirical work suggest that plant age, size and productivity play important roles in determining plant survival. The LRD does not record the precise start year for any plant. Instead, we only know the first year the plant appears in a Census of Manufactures starting with the 1963 Census. Our measure of plant age is the difference between the current year and the first recorded Census year. Plants that are in their first Census are given an age of zero. Plants that die are 8.6 years old in our sample while plants that survive are 11.7 years old according to this measure (Table 1). The marginal effect of age on the probability of death is negative and significant.

Following previous work, we measure the size of a plant by the log of its total employment. Survivors are more than 60% larger than exits and the marginal probability of death is sharply declining in plant size.

As is well known, accurately measuring multi-factor productivity at the plant is quite difficult. Since we have only single observations for many of the establishments in the sample, we are constrained in our choice of productivity measures. We estimate a simple five input production function

[17] We thank Marc Melitz for suggesting this measure. Our measure is similar to one calculated by Dunne and Roberts (1991) who find their measure of "producer volatility" is both more pronounced and more persistent than entry, exit or net entry, suggesting it is a good proxy for sunk costs.

in logs for each industry and year,

$$\ln Y_{pit} = \beta^0_{it} + \beta^1_{it} \ln P_{ipt} + \alpha^2_{it} \ln N_{ipt} + \beta^3_{it} \ln K_{ipt} + \beta^4_{it} \ln B_{ipt} + \beta^5_{it} \ln M_{ipt} + \epsilon_{ipt} \quad (5)$$

where Y is gross output of the plant in year t, P and N are the number of production and non-production workers at the plant, K is the book value of machinery and equipment, B is the book value of buildings and structures and M is the value of purchased inputs and energy. Recognizing that we are unable to adequately control for the co-movement of markups and productivity, or the co-movements of variable inputs and productivity, we use ϵ_{ipt} as our measure of plant total factor productivity. By construction the measure is mean zero for each industry in each period. Survivors are 0.9% more productive than the average plant in the industry and 3.3% more productive that plants that fail (Table 1). The marginal effect of our productivity measure on the probability of death is negative and significant.

4.1.6. Plant Input Intensities

As discussed in Section 2., endowment-based trade theories predict declining output in U.S. industries with low capital intensity and skill intensity. A simple extension of the theory along the lines of a Dornbusch-Fischer-Samuelson model to incorporate within industry heterogeneity also leads us to expect that higher plant capital and skill intensity will reduce the probability of plant closure.[18]

Capital intensity at the plant is measured by the log of the capital-labor ratio. Surviving plants are 31% more capital intensive than exits and the marginal effect of capital intensity on the probability of death is negative and strongly significant.

Skill intensity is harder to measure in the LRD as there is relatively little information on the characteristics of the workforce. We construct three measures to identify plants that employ relatively skilled workers. First, we use the share of non-production workers in the total workforce. This measure has some well-known problems as a measure of skill. Most notably, non-production workers can be relatively skilled, e.g. managers, or relatively unskilled, e.g. janitors. The non-production worker ratio

[18] The intra-industry model of Olley and Pakes (1996) predicts that physical capital intensity will be positively correlated with plant survival.

may have an additional problem in that plants performing poorly with a relatively high probability of future failure may release production workers first.[19] This would raise the non-production worker ratio for plants with a higher probability of death. In fact, there is no difference in the average non-production ratio across surviving and dying plants (Table 1). In the univariate probit, however, the marginal probability of death is significantly decreasing in the share of non-production workers.

Our other two skill measures are based on the average wages paid to the each of the two types of labor, production and non-production. Both types of wages are significantly higher at surviving plants, 13% in each case. In addition, the probit estimates show a strong negative relationship between log wages and the probability of plant shutdown.

4.1.7. Agglomeration and Geography

Our controls for geographic effects on plant closure come from Duranton and Puga (2000). For regions, we use the Labor Market Areas (LMAs) constructed by the Bureau of Economic Analysis based on common commuting patterns. In the 50 states in our sample there are 183 LMAs. Working with the LMA as the unit of geographic analysis has several advantages. First the LMAs cover the entire U.S., rather than just metropolitan areas. Second, LMAs can cross state lines and large states can have multiple LMAs, thus allowing them to correspond more closely to areas of related economic activity.

The measure of regional relative specialization is given by

$$RZI_r = \max_i \left(\frac{s_{ri}}{s_i} \right)$$

where s_{ri} is the share of industry i in region r and s_i is the share of industry i in total national employment.

The measure of regional relative diversity is given by

$$RDI_r = \frac{1}{\sum_i |s_{ri} - s_i|}$$

[19] This assumes that production workers are closer to a true variable input.

where s_{ri} is the share of industry i in region r and s_i is the share of industry i in total national employment. Plant deaths should be decreasing in relative regional specialization and increasing in relative regional diversity.

As shown in Table 1, plants that die are in regions that are more diverse and in regions that are less specialized as predicted by Duranton and Puga (2000). Running a simple probit of plant death on both geographic measures, we find that plant deaths are significant related to regional specialization (negatively) and to regional diversity (positively) in the expected directions. In the next section we present our multivariate specifications, including both geographic measures as controls.

5. Empirical results

We now estimate our base multivariate specification, first without the measures of international competition in Table 3 and then including the low-wage competition measures and their interaction effects in Tables 4 and 6. Table 7 provides a summary of both the univariate and multivariate probit results.

Columns 1-3 in Table 3 report our base specification pooled across years for all plants in the sample. All plant characteristics (except plant export status) are included along with our measures of firm ownership structure, regional specialization, industry entry costs and year dummies. Column 3 reports the change in the probability of death for a one standard deviation increase in the plant and firm characteristics.

As expected, the probability of plant shutdown is significantly decreasing in industry entry costs, plant age, plant size and plant productivity. Increasing plant size by one standard deviation reduces the probability of shutdown by 5.2 percentage points, and a comparable increase in age is associated with a 3.3 percentage point drop.[20] The probability of death falls 1.5 percentage points for a one standard deviation increase in productivity.

Even controlling for age, size and productivity, we find significant roles for plant factor intensity in the shutdown decision. Both capital and skill-intensive plants are less likely to die. The capital-labor ratio, production worker wage, and non-production worker wage are all significantly nega-

[20] The change in probability is calculated with all variables at their sample means, increasing only the relevant variable.

tively associated with plant failure, with the probability falling 0.8, 1.6 and 1.2 percentage points respectively for a one standard deviation increase. The ratio of non-production workers is the sole exception as it is positively associated with shutdown.

The effects of our geography variables remain unchanged. Increased relative regional specialization in a dominant industry decreases the probability of exit while increased relative regional diversity across industries increases the probability of closure.

5.0.8. Firms and plant deaths

Next, we turn to the role of firm ownership in plant shutdowns. Relative to the unconditional results reported in Section 4.1.2., we find substantial changes in the role of firm characteristics in shutdowns once we condition on plant characteristics. Unconditionally, plants that are part of a multi-plant firm are less likely to be shut down than single-plant firms. However, this is driven entirely by the 'good' characteristics of plants that are part of larger firms. Controlling for plant size, age, factor intensity, etc., we find that the being part of a larger firm significantly *increases* the probability of death at the margin. The magnitude of the effect is very large and is stronger for plant that are 'orphans' than for 'siblings', 8.0 and 3.1 percentage points respectively, although both are significant at the 1% level. The stronger effects on orphans matches the theoretical predictions from the declining industry literature that diversified firms are more likely to close plants. Multi-plant firms are able and willing to use the plant shutdown margin to adjust employment and output. The difference in the shutdown probability may point to separate sunk costs of entry for the firm and the plant.

Ownership changes at the plant show a similar pattern. Plants that have experienced a change in ownership in the previous five year period have characteristics that decrease their probability of death. This suggests that typically ownership changes occur at 'good' plants. However, controlling for other plant and firm attributes, we find that 'takeover' targets are *more likely* to shut down than plants with unchanged ownership by 6.2 percentage points. We cannot tell if this dramatically higher probability of failure is related to a poor match between plant and firm or a planned rationalization of capacity by the firm.

Finally, we consider whether the multinational status of the owning firm is related to the probability of shutdown. Once again the unconditional relationship suggests that domestic plants owned by U.S. multinationals have 'good' attributes that make them less likely to fail. Controlling for plant characteristics and other firm ownership characteristics, we find that the marginal effect of multinational ownership is to *increase* the probability of exit by 3.6 percentage points. This matches the notion of 'footloose' capital proposed by Rodrik (1997). The foreign assets of the multinational firm may increase their flexibility and thus raise the probability that they will close one of their domestic plants. This also matches the evidence of Brainard and Riker (1997a,b) and Braconier and Ekholm (2000) that multi-nationals have, in effect, an increased elasticity of labor demand due to their ability to shift production across locations within the firm.

5.1. Product markets and shutdowns

Both unconditionally and conditionally, plants that produce more products have lower probabilities of failure. Moving from 1 to 2 products reduces the plant death probability by 2.5 percentage points, moving to 3 products lowers the probability an additional 3.7 percentage points. Plants with large numbers of products, 4 or more, are dramatically less likely to fail than a plant with a single product (8.5 percentage points).

In columns 4-5 of Table 3, we add plant export status to the base specification. Due to the limited availability of the export variable, we are able to run the probits only for the 1987-1997 panels. None of the other variables change sign, or substantively change their magnitude, from the full sample estimation suggesting the underlying relationships are not changing over time. Exporting by the plant remains significantly positively associated with plant survival. Conditional on all the other variables, the probability of death at exporters is 4.2 percentage points lower than at non-exporters. The sign of the export variable is unchanged from the unconditional regressions reported above. Although the selection and survival models of Melitz (2002) and BEJK (2000) predict that exporting will be associated with lower failure rates, this relationship is driven by the underlying plant productivity. Our strong results on exporting in the full specification suggest either that exporting has a direct positive effect on survival or that exporting is correlated with other unobserved characteristics of the firm that increase survival.

5.2. Imports from low wage countries

We now consider the role of imports from low wage countries in shaping industry structure through plant deaths. For our import measures, we use the value share of imports, the product number share and the interaction of the two as described in Section 3.. We expect to see two types of effects on shutdowns. First, plants in industries that are facing high or rising imports from low wage countries should be more likely to close. To test this we rerun our base specifications with the inclusion of the three import measures. Second, within industries, we do not expect to see an equal impact on all plants. Plants at a comparative disadvantage, either because of low capital and skill intensities or low productivity, should be more likely to fail in the face of high imports. Thus, within industries, these low skill, low capital, and low productivity plants should be more likely to close than their capital and skill intensive counterparts. To capture this within industry heterogeneity, we interact plant characteristics with the $product \times value$ import measure. The interacted plant characteristics are capital intensity, the three skill measures, and productivity. Tables 4 and 6 contains the results including the measures of low wage imports without and with the interaction terms respectively.

Imports from low wage countries remain significantly positively related to the probability of plant death even after controlling for other plant, industry, and regional characteristics. This is best seen in Figure 3 which shows the conditional relationship between the low wage import measures and the increased probability of plant death. The surface shows the increase in the shutdown probability as the level of low wage import shares rise for the industry.[21] Most important is the large increase when both the share of products and the share of import values from low wage countries are high. Remembering that in our sample the unconditional average probability of death is 26%, these increases associated with high import competition are still very large, although smaller than the unconditional results in Figure 2.[22]

[21] As in Figure 3, each point on the surface represents the difference in the probability of death for a plant (with average characteristics) in an industry with the associated levels of low wage competition from the probability for the same plant in the industry with the median levels of low wage competition.

[22] Note that there is almost no change in sign, significance or magnitude of the coeffi-

In Table 5, we show the distribution of effects of low wage import shares relative to the median industry for 1977 and 1992, the endpoints of our panel. In 1977, most industries had relatively low exposure to low wage imports. Even so 5% of the industries faced enough competition from low wage countries to raise the conditional probability of plant death by at least 2.5 percentage points.

By 1992, many more industries were facing substantial import penetration from low wage countries. The probability of plant death was raised by at least 2.5 percentage points in more than 14% of industries, and more than 7% of the industries saw their failure probabilities rise by 5 or more percentage points.

One additional point of interest is the large difference between the unconditional and conditional effects of low wage imports. This suggests that imports from low wage countries are arriving in industries that are the least skill and capital intensive, as predicted by endowment-based models of international trade.

5.2.1. Heterogeneity within industries

While the previous results show the strong effect of import competition on plant mortality across industries, we also suspect that plants within an industry are differentially exposed to low wage countries. Existing models of plant heterogeneity and international trade, i.e. Melitz (2002) and BEJK (2000), focus on the role of productivity in plant shutdowns due to trade. In both cases, low productivity plants within an industry are more likely to close in the face of increased import competition. However, these models do not distinguish between competition from low wage and high wage countries. Given the nature of our trade measures, we expect to see a significant role for plant input intensities in the face of competition from low wage countries. Within an industry, low wage competition will directly affect less capital and skill intensive plants within an industry. To examine such effects, we interact low wage import shares with selected plant attributes. In particular, we consider both plant productivity and plant factor intensity (capital and skill).

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cients on other plant, firm and industry characteristics between Table 3 and Table 4, i.e. without and with the low wage competition measures.

We interact the plant characteristics with the *product* × *value* import measure and report the results in Table 6.[23] The interaction terms for all the measures of factor usage at the plant have negative coefficients. With the exception of production worker wages, the coefficients are all significant at the 10% level. This suggests that within industries facing significant competition from low wage countries, capital and skill intensity offset some of the increased probability of shutdown. Interestingly, there is no role for the interaction of plant productivity and low wage imports, the coefficient has the wrong sign and is not significant.[24]

To understand the importance of these within industry effects, we consider the probability of failure for a plant with high capital and skill intensity and one with low capital and skill intensity. Our high (low) capital intensity plant has $\log(K/L)$ one standard deviation above (below) the mean.[25] The top panel in Figure 4 shows the probability of failure for our low capital plant while the bottom panel shows the probability of failure for the high capital plant. Both the levels and slopes of the surfaces differ substantially for the two types of plants. For both types of plants, the probability of death is increasing in import shares from low wage countries. Capital and skill intensity at the plant level is not sufficient to completely offset the effects of such competition. In addition, as expected, the capital and skill intensive plant is less likely to fail at any level of competition from low wage countries than the low capital plant, i.e. the surface is lower for every pair of the import measures.

The biggest difference between the plant types is in the interaction of low wage imports and capital intensity, i.e. the slope of the surfaces. The probability of death increases dramatically for the low capital intensity plant as the share of imports from low wage competition rises. For the high capital plant the increase in imports raises the probability of shutdown, but

[23] We limit the interactions to the most important of our three competition terms to manage the number of reported coefficients. Coefficients on other variables in the base specification are suppressed but do not change sign, significance, or magnitude.

[24] The possibility remains that plant productivity plays a role in differentiated product industries facing competition from comparable high skill countries.

[25] High capital plants also have higher skill intensity as measured by both wages and non-production worker shares. We adjust the skill intensity characteristics as well. Our high capital plant has a non-production worker share 0.07 standard deviations above the mean, non-production wages 0.29 standard deviations above the mean, and production wages 0.50 standard deviations above the mean.

by a far lower amount. In 1992, moving from the median industry in terms of low wage import shares, i.e. glass products SIC 3231, to the industry at the 90th percentile, canvas products SIC 2394, raises the probability of failure for the low capital plant by 4.4 percentage points to 30.1% while it raises the probability of failure for the high capital plant by 2.0 percentage points to 23.7%.

5.2.2. Robustness

To further evaluate the robustness of our results, we consider two additions to our multivariate specification. First, we include a measure of industry import penetration to address the concern that our low wage import shares are merely reflecting overall import activity rather than a change in the source of imports. Second, we include industry fixed effects. Industry fixed effects perform two roles: first, they control for the possibility that low wage imports are entering precisely in industries where the ex-ante probability of death is highest. In addition, they soak up all time-invariant industry effects.

In Table 8, we report the coefficients from four probits. Column 1 contains our multivariate specification with the low wage measures and their interactions with plant characteristics, i.e. the probit reported in Table 6.[26] Column 2 includes a measure of industry import penetration, calculated as the average ratio of imports to domestic absorption over the preceding five years (production less exports plus imports). Column 3 includes industry fixed effects while Column 4 has both import penetration and industry fixed effects.

The results are quite stable. None of the coefficients on the plant, firm or industry characteristics changes sign or significance.[27] Low wage import shares continue to be positively correlated with the probability of plant death, even when both industry fixed effects and import penetration are included. The signs of the interactions of plant characteristics and low wage measures are unchanged, although the magnitude of the interaction with capital intensity is reduced and is no longer significant one industry

[26] The numbers in the table are the coefficients off the probit, rather than the marginal probabilities, to facilitate ease of comparison.

[27] The unchanged coefficient on the measure of entry cost suggests that industry fixed effects may not be an effective way to proxy for industry sunk entry costs.

fixed effects are included.[28]

6. Conclusions

Our goal in this paper has been to provide an in-depth look at the determinants of plant failure. To do this, we have expanded the set of factors that affect plant shutdowns to include factor input intensities, product market characteristics, firm structure, and import shares from low wage countries. Using data on the entire U.S. manufacturing sector from 1977-1997, we find that each of our four areas of focus provides important new insights into the plant shutdown decision.

We confirm previous research in finding that plant size, age and productivity are important determinants of plant survival. Even controlling for these attributes, we find that the input mix at the plant is also correlated with survival. Death rates are greater for plants with low capital-labor ratios and those with relatively low skilled workers. In particular, high capital, high skill plants are better able to survive increases in import shares from low wage countries.

The characteristics of product markets are strongly associated with the likelihood of exit. Single-product plants are much more likely to fail in any five year period than plants producing multiple goods. The probability of survival increases as the number of products made at the plant rises, even controlling for other plant attributes. Exporting plants are far less likely to die than non-exporters, as much as 15% even after accounting for plant size, productivity, factor intensity and ownership structure.

Our research emphasizes the difference between multi-unit firms and single establishment firms in the shutdown process. We provide direct evidence that multi-plant firms use the shutdown margin more often than their single plant counterparts. The nature of the firm plays a crucial role in plant shutdowns. Plants that are part of a larger firm are unconditionally far less likely to shut down than a single-plant firm. However, this finding is completely reversed once we condition on other plant characteristics such as age, size, productivity and capital intensity. For similar plants, we find that multi-plant firms are actually *more* likely to close a plant. Similarly,

[28] Import penetration does raise the probability of plant death, although is it not signficant once industry fixed effects are included.

plants that have changed ownership have positive attributes that make them less likely to die. However, conditioning on the plant's qualities, a new owner is significantly more likely to close the recent acquisition. Finally, we investigate the relationship between multinational ownership and plant closure. For comparable plants, we find that a U.S. multinational is significantly more likely to close a plant than a domestic firm.

A major goal of the paper is to examine the role of import competition from low wage countries on plant survival. We use new industry-specific measures on the share of imports from low wage countries and find that such import penetration sharply increases the probability of plant death. We also find that low wage imports do not affect all plants equally. Within an industry, the least skill and capital intensive plants have the greatest increase in their shutdown probabilities when low wage countries enter their markets. Interestingly, there is no interaction effect of low wage import competition with plant productivity, unlike the predictions of several recent plant-based models of trade. These results suggest that increased imports from low wage countries have played a role in the dramatic shift of US manufacturing towards plants with higher skill and capital intensity and higher wages.

References

Albuquerque, Rui and Sergio Rebelo (2000) "On the Dynamics of Trade Reform", *Journal of International Economics*, 51, 21-48.

Baden-Fuller, Charles W. F., (1989) "Exit from Declining Industries and the Case of Steel Casings," *Economic Journal*, 99, 949-961.

Bernard, Andrew B., Jonathon Eaton, J. Bradford Jensen, and Samuel S. Kortum (2000). "Plants and Productivity in International Trade." NBER working paper #7688.

Braconier, Henrik and Karolina Ekholm, (2000) "Swedish Multinationals and Competition from High- and Low-Wage Locations", *Review of International Economics* 8(3), 448-461.

Brainard, Lael and David Riker, (1997a) "Are U.S. Multinationals Exporting U.S. Jobs?", NBER Working Paper # 5958.

Brainard, Lael and David Riker, (1997b) "U.S. Multinationals and Competition from Low Wage Countries", NBER Working Paper # 5959.

Deily, Mary, (1991) "Exit Strategies and Plant-closing Decisions," *RAND Journal of Economics*, 22(2), 250-263.

Doms, Mark E. and J. Bradford Jensen, (1998) "Comparing Wages, Skills, and Productivity between Domestically and Foreign-Owned Manufacturing Establishments in the United States" in *Geography and Ownership as Bases for Economic Accounting*, Baldwin, Robert E; Lipsey, Robert E; Richardson, J. David, eds, NBER Studies in Income and Wealth, vol. 59. Chicago and London: University of Chicago Press.

Dumais, Guy, Glenn Ellison, and Edward L Glaeser, (2002) "Geographic Concentration as a Dynamic Process", *Review of Economics and Statistics*, Vol. 84(2), 193-204.

Dunne, Timothy, and Mark J. Roberts, (1991) "Variation in Producer Turnover Across US Manufacturing Industries," in *Entry and Market Contestability: An International Comparison*, P.A. Geroski and J Schwalbach, Ed.s, Basil Blackwell.

Dunne, Timothy, Mark J. Roberts, and Larry Samuelson, (1988) "Patterns of firm entry and exit in US manufacturing industries", *Rand Journal of Economics*, Vol. 19(4), 495-515.

Dunne, Timothy, Mark J. Roberts, and Larry Samuelson, (1989) "The Growth and Failure of US Manufacturing Plants", *Quarterly Journal of Economics*, Vol. 104(4), 671-698.

Duranton, Gilles and Diego Puga, (2000) "Diversity and Specialisation in Cities: Why, Where and When Does It Matter?" *Urban Studies*, vol. 37, no. 3, pp. 533-55.

Ericson, Richard and Ariel Pakes, (1995) "Markov-perfect industry dynamics: a framework for empirical work." *Review of Economics Studies*, 62, 53–82.

Foster, Lucia, John Haltiwanger, and CJ Krizan, (1998) "Aggregate Productivity Growth: Lessons from Microeconomic Evidence", National Bureau of Economic Research Working Paper: 6803, November.

Gibson, John K. and Richard I. D. Harris, (1996) "Trade Liberalization and Plant Exit in New Zealand Manufacturing." *Review of Economics and Statistics*, Vol. 78(3), 521-529.

Ghemawat, Pankaj, and Barry Nalebuff, (1985) "Exit", *Rand Journal of Economics*, 16(2), 184-194.

Hopenhayn, Hugo, (1992a) "Entry, Exit, and Firm Dynamics in Long Run Equilibrium." *Econometrica*, 60(5), 1127-1150.

Hopenhayn, Hugo, (1992b) " Exit, Selection and The Value of Firms." *Journal of Economic Dynamics and Control*, 16, 621-653.

Jovanovic, Boyan, (1982) "Selection and the Evolution of Industry." *Econometrica*, 50, 649-670.

Lieberman, Marvin, (1990) "Exit from Declining Industries: "Shakeout" or "Stakeout"? *RAND Journal of Economics*, 21(4), 538-554.

Melitz, Marc J., (2002) "The Impact of Trade on Intra-Industry Reallocations and Aggregate Industry Productivity", NBER working paper #8881.

Olley, Steven G. and Ariel Pakes, (1996) "The Dynamics of Productivity in the Telecommunications Equipment Industry," *Econometrica*, 64(6), 1263-97.

Rodrik, Dani, (1997) *Has Globalization Gone Too Far*. Institute for International Economics, Washington, DC.

Schott, Peter K., (2002), "Moving Up and Moving Out: Product Level Exports and Competition from Low Wage Countries." Yale School of Management mimeo.

Whinston, Michael, (1988) "Exit with Multi-Plant Firms." *RAND Journal of Economics*, 19(4), 568-588.

A Appendix - Low Wage Countries 1972-1992

Afghanistan	China	India	Pakistan
Albania	Comoros	Kenya	Rwanda
Angola	Congo	Lao PDR	Samoa
Armenia	Equatorial Guinea	Lesotho	Sao Tome
Azerbaijan	Eritrea	Madagascar	Sierra Leone
Bangladesh	Ethiopia	Malawi	Somalia
Benin	Gambia	Maldives	Sri Lanka
Bhutan	Georgia	Mali	St. Vincent
Burkina Faso	Ghana	Mauritania	Sudan
Burundi	Guinea	Moldova	Togo
Cambodia	Guinea-Bissau	Mozambique	Uganda
Central African Rep	Guyana	Nepal	Vietnam
Chad	Haiti	Niger	Yemen

Not all countries are categorized as low wage in every year.
For details on the specific years, see Schott (2002).

Table 1: Means and Pooled Univariate Probits, 1977-1997 [29]

	(1) Survivors (mean)	(2) Deaths (mean)	(3) Probability Change $\partial\Phi/\partial x$
Entry Cost	**-.32**	-.35	-.755*
Age (years)	**11.7**	8.6	-.008*
Size (log employment)	**3.71**	3.22	-.056*
Capital Intensity (lnK/L)	**3.14**	2.87	-.047*
Non-Production/Total Employment	.301	.300	-.013*
Production Wage (log 1000$/worker)	**3.30**	3.17	-.114*
Non-Production Wage (log 1000$/worker)	**2.86**	2.73	-.084*
log Total Factor Productivity	**.0086**	-.0242	-.078*
Exporter	**.221**	.120	-.126*
Takeover	**.083**	.073	-.029*
Multi-plant firm	**.341**	.276	-.036*
Sibling	**.274**	.206	-.070*
Orphan	.067	.070	-.010*
US Multinational	**.085**	.062	-.062*
# of products	**3.52**	2.56	
2 products			-.057*
3 products			-.111*
4+ products			-.156*
Relative Regional Specialization			-.0002*
Relative Regional Diversity			.0751*
Product Share - Low Wage Imports			-.301*
Value Share - Low Wage Imports			.027*
Product Share×Value Share			.966*

[29] Means are calculated separately for survivors and deaths in Columns 1 and 2 respectively, pooled across all years in the sample. Double lines indicate a probit with multiple independent variables. **Bold** indicates a significant difference (5%) between survivors and deaths. Column 3 reports results from a probit of death(=1) on the variable and year dummies. Coefficients on year dummies are suppressed. The reported number is the marginal probability change at the mean of the independent variable. * indicates significant at the 1% level.

Table 2: Effects of Low Wage Import Competition on The Unconditional Probability of Shutdown[30]

Percentage Points	1977	1992
< -2.5	2	20
[-2.5, 2.5)	287	226
[2.5, 7.5)	32	44
[7.5, 12.5)	11	16
[12.5, 17.5)	2	8
> 17.5	3	23

[30] Ranges in column 1 represent the increase (or decrease) in the probability of death relative to an industry with median levels of low wage competition controlling only for year effects. Columns 2 and 3 contain the number of industries in each range for 1977 and 1992 respectively.

Table 3: The Probability of Plant Death - Pooled Multivariate Probits [31]

	(1) 1977-97 ΔProb. $\partial\Phi/\partial x$	(2) std.err.	(3) Δ%	(4) 1987-97 ΔProb. $\partial\Phi/\partial x$	(5) std.err.
Entry Cost	-.485*	.0076		-.491*	.0114
Age (years)	-.004*	.0000	-3.3	-.004*	.0001
Size (log employment)	-.041*	.0006	-5.2	-.035*	.0009
Capital Intensity (lnK/L)	-.010*	.0007	-0.8	-.011*	.0010
Non-Production/Total Employment	.012*	.0039	0.6	.038*	.0052
Production Wage (log 1000$/worker)	-.040*	.0018	-1.6	-.043*	.0026
Non-Production Wage (log 1000$/worker)	-.027*	.0014	-1.2	-.020*	.0020
log Total Factor Productivity	-.053*	.0024	-1.5	-.050*	.0031
Exporter				-.048*	.0025
Takeover	.062*	.0028		.068*	.0037
Sibling (multi-plant firm)	.031*	.0019		.023*	.0027
Orphan (multi-plant firm)	.080*	.0031		.086*	.0045
US Multinational	.036*	.0030		.050*	.0046
2 products	-.028*	.0017		-.014*	.0024
3 products	-.064*	.0020		-.068*	.0028
4+ products	-.088*	.0016		-.089*	.0022
Relative Regional Specialization	-.0002*	.0000		-.0002*	.0000
Relative Regional Diversity	.049*	.0047		.052*	.0063

[31] Columns 1-3 report results from a probit of death(=1) on the complete multivariate specification excluding the exporter dummy for 1977-1997. Columns 4 and 5 report results from a comparable specification including the exporter dummy for 1987-1997. Coefficients on year dummies are suppressed. The reported number in Columns 1 and 4 is the marginal probability change at the mean of the independent variable or the change in probability for a dummy variable switching from 0 to 1. The reported number in Column 3 is the percentage point change in the probability of death for a 1 standard deviation increase in the variable from its mean. * indicates significance at the 1% level.

Table 4: Pooled Multivariate Probits with Import Competition Variables [32]

	(1) ΔProb. $\partial\Phi/\partial x$	(2) std.err.	(3) ΔProb. $\partial\Phi/\partial x$	(4) std.err.
Entry Cost	-.468*	.0079	-.453*	.0121
Age (years)	-.004*	.0000	-.004*	.0001
Size (log employment)	-.042*	.0006	-.037*	.0009
Capital Intensity (lnK/L)	-.009*	.0008	-.009*	.0010
Non-Production/Total Employment	.021*	.0039	.052*	.0053
Production Wage (log 1000$/worker)	-.038*	.0019	-.041*	.0026
Non-Production Wage (log 1000$/worker)	-.026*	.0014	-.020*	.0020
log Total Factor Productivity	-.054*	.0024	-.051*	.0031
Exporter			-.048*	.0025
Takeover	.062*	.0028	.068*	.0037
Sibling (multi-plant firm)	.029*	.0019	.020*	.0027
Orphan (multi-plant firm)	.079*	.0031	.085*	.0045
US Multinational	.037*	.0030	.051*	.0046
2 products	-.026*	.0017	-.011*	.0024
3 products	-.062*	.0020	-.066*	.0029
4+ products	-.087*	.0016	-.085*	.0022
Relative Regional Specialization	-.0002*	.0000	-.0002*	.0000
Relative Regional Diversity	.047*	.0047	.049*	.0063
Product Share - Low Wage Imports	-.015*	.0031	-.017⊠	.0043
Value Share - Low Wage Imports	.077*	.0297	.077*	.0441
Product Share×Value Share	.107*	.0414	.139*	.0540

[32] Columns 1 and 2 report results from a probit of death(=1) on the complete multivariate specification plus the levels of the three import competition variables excluding the exporter dummy for 1977-1997. Columns 3 and 4 report results from a comparable specification including the exporter dummy for 1987-1997. Coefficients on year dummies are suppressed. The reported number is the marginal probability change at the mean of the independent variable or the change in probability for a dummy variable switching from 0 to 1. ⊠ indicates significance at the 10% level. * indicates significance at the 1% level.

Table 5: Effects of Low Wage Import Competition on The Conditional Probability of Shutdown[33]

	1977	1992
< -2.5	0	0
[-2.5, 0)	117	106
[0, 2.5)	203	183
[2.5, 5.0)	9	23
[5.0, 7.5)	7	14
> 7.5	1	11

[33] Ranges in column 1 represent the increase (or decrease) in the probability of death relative to an industry with median levels of low wage competition, controlling for all plant, firm and industry variables in the basic multivariate specification (see Table 4). Columns 2 and 3 contain the number of industries in each range for 1977 and 1992 respectively.

Table 6: Probits with Import Competition Variables and Interactions with Plant Characteristics [34]

	(1) ΔProb. $\partial\Phi/\partial x$	(2) std.err.
Product Share - Low Wage Imports	-.010*	.0032
Value Share - Low Wage Imports	.096*	.0304
Product Share×Value Share	.676*	.0906
Interactions w/ (Product×Value)		
Capital Intensity (lnK/L)	-.021⊠	.0129
Non-Production/Total Employment	-.518*	.0875
Production Wage (log 1000$/worker)	-.048	.0246
Non-Production Wage (log 1000$/worker)	-.106*	.0246
log Total Factor Productivity	.017	.0356

[34] Columns 1 and 2 report results from a probit of death(=1) on the complete multivariate specification. Coefficients on plant and firm characteristics and year dummies are suppressed. The reported number is the marginal probability change at the mean of the independent variable or the change in probability for a dummy variable switching from 0 to 1. ⊠ indicates significance at the 10% level. * indicates significance at the 1% level.

Table 7: Probability of Plant Death: Summary of Univariate and Multivariate Results[35]

	Unconditional	Conditional
Entry Cost	-	-
Age (years)	-	-
Size (log employment)	-	-
Capital Intensity (lnK/L)	-	-
Non-Production/Total Employment	-	(+)
Production Wage (log 1000$/worker)	-	-
Non-Production Wage (log 1000$/worker)	-	-
log Total Factor Productivity	-	-
Exporter	-	-
Takeover	-	+
Sibling (multi-plant firm)	-	+
Orphan (multi-plant firm)	-	+
US Multinational	-	+
Multiple products	-	-
Relative Regional Specialization	-	-
Relative Regional Diversity	+	+
Product Share - Low Wage Imports	-	-
Value Share - Low Wage Imports	+	+
Product Share×Value Share	+	+
Interactions w/ (Product×Value)		
Capital Intensity (lnK/L)		-
Non-Production/Total Employment		-
Production Wage (log 1000$/worker)		{-}
Non-Production Wage (log 1000$/worker)		-
log Total Factor Productivity		({+})

[35] Columns 1 and 2 summarize the results from the univariate and multivariate probits. A minus [-] or plus [+] sign indicates that the variable is negatively or positively correlated with the probability of plant death. Parentheses indicate that the result was the opposite sign from that expected, while curly bracket {} indicate that the coefficient was not significantly different from zero at the 10% level.

Table 8: Robustness Checks [36]

	(1)	(2)	(3)	(4)
Entry Cost	-1.461*	-1.049*	-1.808*	-1.440*
Age (years)	-.012*	-.012*	-.012*	-.012*
Size (log employment)	-.132*	-.141*	-.177*	-.178*
Capital Intensity (lnK/L)	-.024*	-.030*	-.022*	-.021*
Non-Production/Total Employment	.098*	.095*	.095*	.089*
Production Wage (log 1000$/worker)	-.117*	-.113*	-.115*	-.119*
Non-Production Wage (log 1000$/worker)	-.072*	-.087*	-.099*	-.102*
log Total Factor Productivity	-.164*	-.164*	-.164*	-.158*
Takeover	.187*	.189*	.185*	.184*
Sibling (multi-plant firm)	.088*	.081*	.086*	.082*
Orphan (multi-plant firm)	.235*	.228*	.218*	.222*
US Multinational	.112*	.120*	.099*	.109*
2 products	-.082*	-.092*	-.079*	-.084*
3 products	-.209*	-.221*	-.196*	-.206*
4+ products	-.283*	-.281*	-.264*	-.270*
Relative Regional Specialization	-.001*	-.001*	-.001*	-.001*
Relative Regional Diversity	0.148*	0.162*	0.135*	0.147*
Product Share - Low Wage Imports	-0.032*	-0.021*	0.071*	0.078*
Value Share - Low Wage Imports	0.301*	0.389*	0.330	0.191
Product Share×Value Share	2.132*	1.950*	1.182*	1.271*
Interactions w/ (Product×Value)				
Capital Intensity (lnK/L)	-0.067⊠	-0.126*	-0.008	-0.008
Non-Production/Total Employment	-1.633*	-1.750*	-1.479*	-1.445*
Production Wage (log 1000$/worker)	-0.150*	-0.162*	-0.232#	-0.233#
Non-Production Wage (log 1000$/worker)	-0.3350*	-0.260*	-0.138⊠	-0.110
log Total Factor Productivity	0.055	0.038	0.011	-0.005
Import Penetration		0.370*		0.060
Industry Fixed Effects			Y	Y

[36] Columns 1 reports results from a probit of death(=1) on the complete multivariate specification. Column 2 includes the measure of average industry import penetration.. Columns 3 includes industry fixed effects. Column 4 includes both import penetration and industry fixed effects.

Coefficients year dummies are suppressed. The reported numbers are the actual coefficient from the probit. ⊠ indicates significance at the 10% level. # indicates significance at the 5% level. * indicates significance at the 1% level.

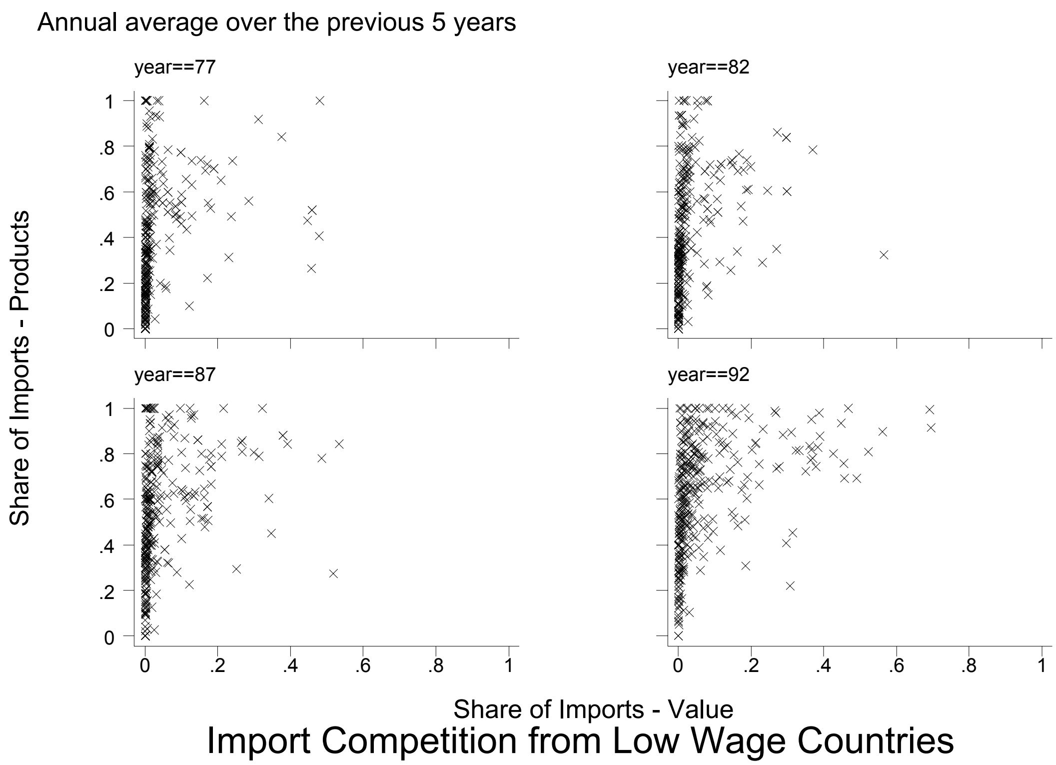
Annual average over the previous 5 years
year==77
year==82
year==87
year==92
Share of Imports - Products
Share of Imports - Value
0
.2
.4
.6
.8
1
Import Competition from Low Wage Countries

Figure 1:

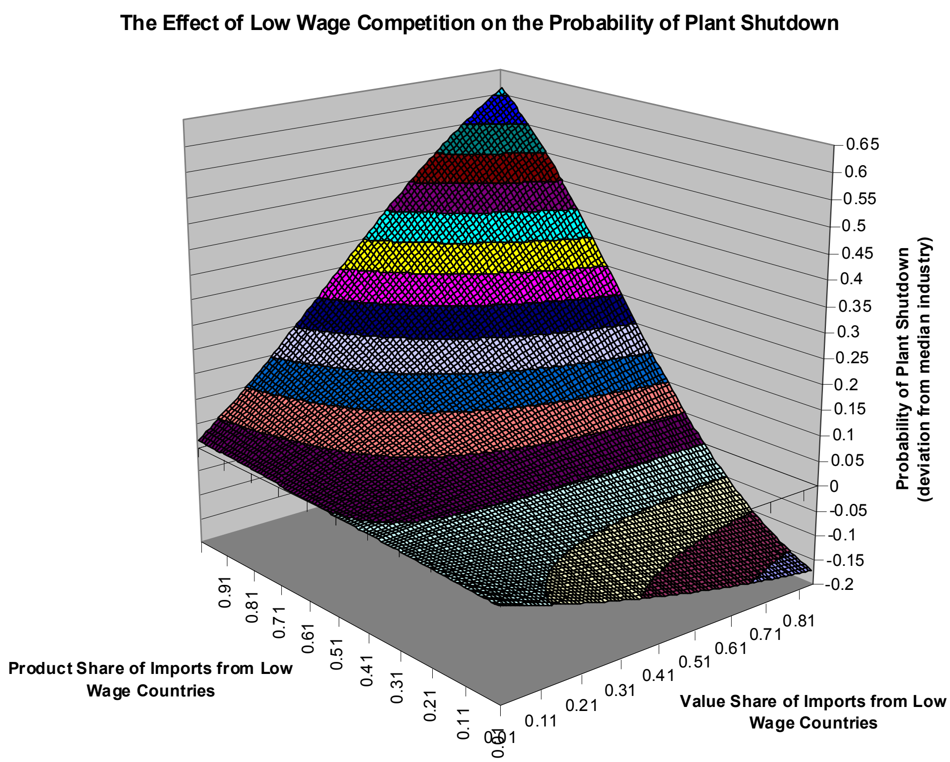
The Effect of Low Wage Competition on the Probability of Plant Shutdown
Probability of Plant Shutdown (deviation from median industry)
0.65
0.6
0.55
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
-0.2
Product Share of Imports from Low Wage Countries
0.91
0.81
0.71
0.61
0.51
0.41
0.31
0.21
0.11
0.01
Value Share of Imports from Low Wage Countries
0.01
0.11
0.21
0.31
0.41
0.51
0.61
0.71
0.81

Figure 2:

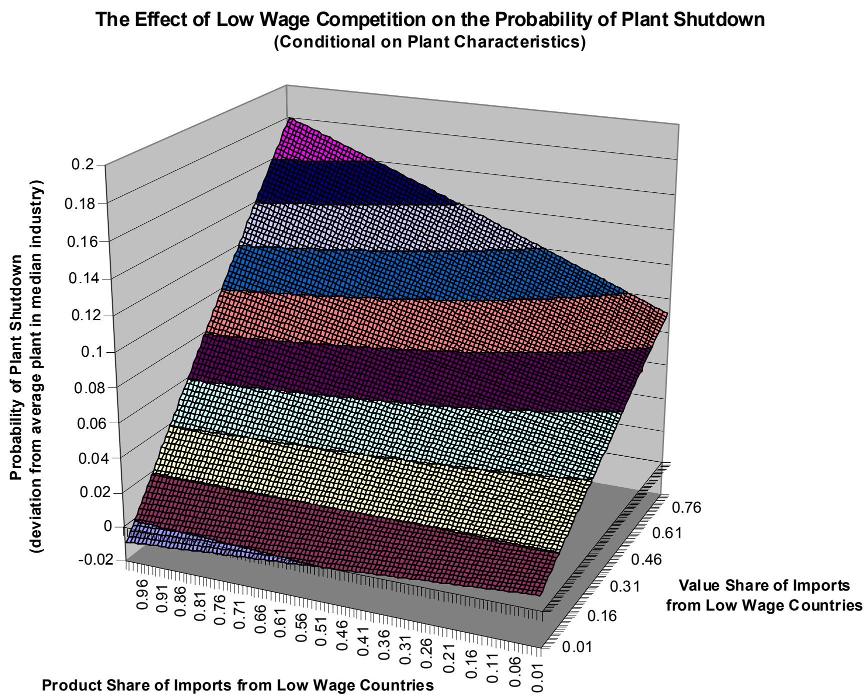
The Effect of Low Wage Competition on the Probability of Plant Shutdown
(Conditional on Plant Characteristics)
Probability of Plant Shutdown
(deviation from average plant in median industry)
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
-0.02
0.96 0.91 0.86 0.81 0.76 0.71 0.66 0.61 0.56 0.51 0.46 0.41 0.36 0.31 0.26 0.21 0.16 0.11 0.06 0.01
Product Share of Imports from Low Wage Countries
0.76
0.61
0.46
0.31
0.16
0.01
Value Share of Imports
from Low Wage Countries

Figure 3:

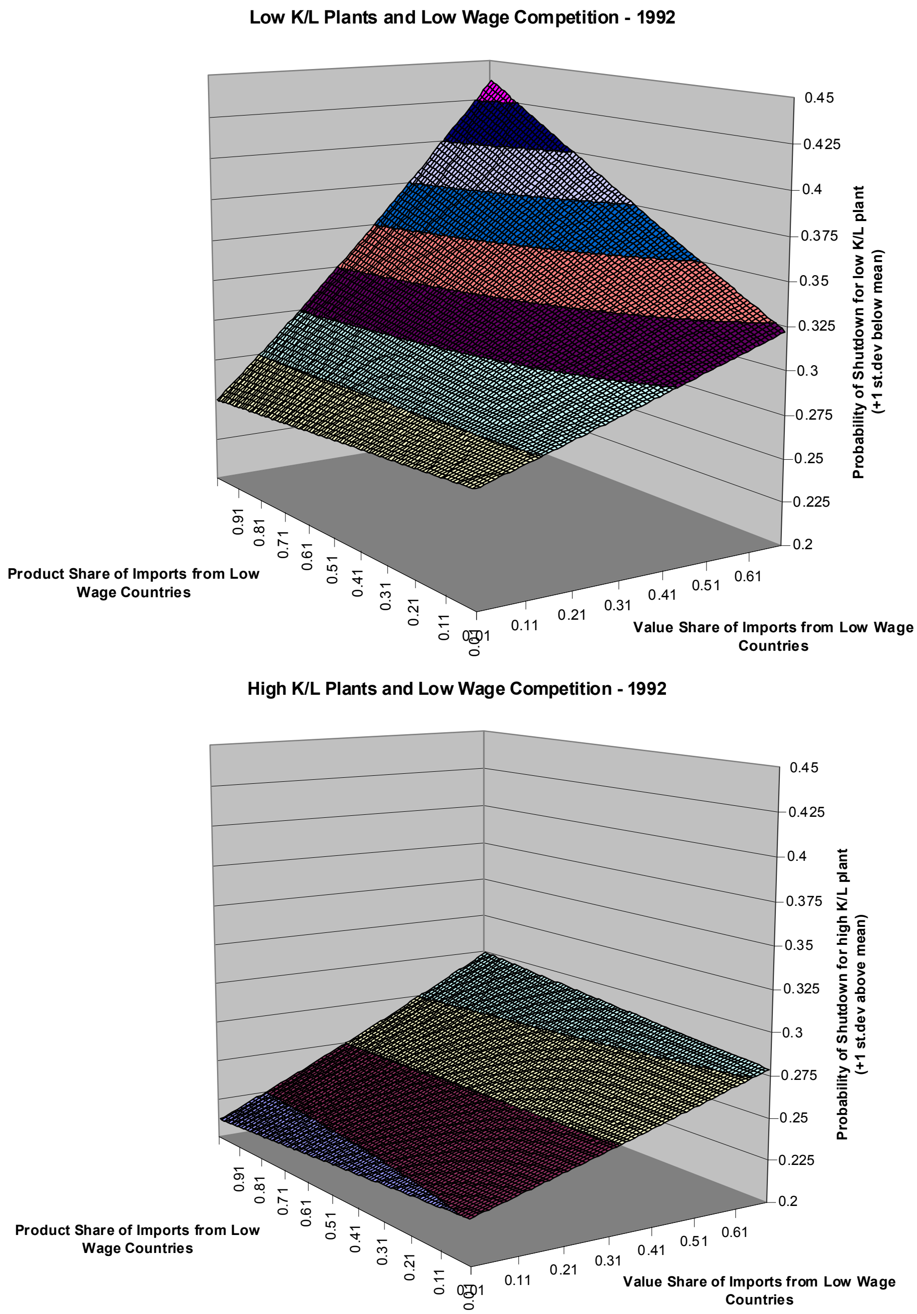
Low K/L Plants and Low Wage Competition - 1992
0.45
0.425
0.4
0.375
0.35
0.325
0.3
0.275
0.25
0.225
0.2
Probability of Shutdown for low K/L plant (+1 st.dev below mean)
0.91
0.81
0.71
0.61
0.51
0.41
0.31
0.21
0.11
0.01
Product Share of Imports from Low Wage Countries
0.01
0.11
0.21
0.31
0.41
0.51
0.61
Value Share of Imports from Low Wage Countries
High K/L Plants and Low Wage Competition - 1992
0.45
0.425
0.4
0.375
0.35
0.325
0.3
0.275
0.25
0.225
0.2
Probability of Shutdown for high K/L plant (+1 st.dev above mean)
0.91
0.81
0.71
0.61
0.51
0.41
0.31
0.21
0.11
0.01
Product Share of Imports from Low Wage Countries
0.01
0.11
0.21
0.31
0.41
0.51
0.61
Value Share of Imports from Low Wage Countries

Figure 4: