Trade costs, firms and productivity ☆

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Abstract

This paper examines the response of U.S. manufacturing industries and plants to changes in trade costs using a unique new dataset on industry-level tariff and transportation rates. Our results lend support to recent heterogeneous-firm models of international trade that predict a reallocation of economic activity towards high-productivity firms as trade costs fall. We find that industries experiencing relatively large declines in trade costs exhibit relatively strong productivity growth. We also find that low-productivity plants in industries with falling trade costs are more likely to die; that relatively high-productivity non-exporters are more likely to start exporting in response to falling trade costs; and that existing exporters increase their shipments abroad as trade costs fall. Finally, we provide evidence of productivity growth within firms in response to decreases in industry-level trade costs.
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1. Introduction

The potential link between trade liberalization and economic growth is fundamental to both international and development economics. To date, research in this area has proceeded in two directions. The first explores the country-level correlation between openness and per capita GDP and asks whether countries with low or falling trade barriers experience higher income growth than countries which remain relatively closed. The second investigates a microeconomic link between countries' trade policies and their firms' productivity. It asks whether firms achieve higher productivity growth by becoming exporters or by being forced to improve as a result of more intense competition with foreign rivals.

This paper focuses on a microeconomic channel that stresses productivity gains via the reallocation of economic activity across firms within industries. This approach is guided by the heterogeneous-firm models of Melitz (2003) and Bernard et al. (2003), which emphasize productivity differences across firms operating in imperfectly competitive industries encompassing horizontally differentiated varieties. The existence of trade costs induces only the most productive firms to self-select into export markets. As a result, when trade costs fall, industry productivity rises both because low-productivity, non-exporting firms exit *and* because high-productivity firms are able to expand through exporting. The most productive non-exporters begin to export, and current exporters, which are the high-productivity firms, expand their foreign sales. In these models, it is the reallocation of activity across firms, *not* intra-firm productivity growth, that boosts industry productivity.[1]

We test the implications of the heterogeneous-firm models by examining whether the evolution of U.S. industry productivity is related to the costs of engaging in international trade. A key contribution of our analysis is the linking of plant-level U.S. manufacturing data to industry-level measures of tariff and transportation costs constructed from U.S. international trade statistics. We use these data to examine the effects of changing trade costs on a variety of plant activities including survival, entry into exporting, export growth and changes in productivity.

We report three main results. First, we demonstrate that industry productivity does indeed rise as trade costs fall. Second, we show that key firm-level implications of the models linking falling trade costs to industry productivity gains are supported by the data. In particular, we find that the probability of plant death is higher in industries experiencing declining trade costs, as is the probability of a plant successfully entering the export market. We also confirm that existing exporters increase their foreign shipments as industry trade costs decline. These results highlight the heterogeneity of firm outcomes within industries and call attention to the fact that there are both winners and losers within industries as a result of trade liberalization. Finally, we report evidence in favor of a relationship between falling trade costs and increases in within-plant productivity: declining trade costs are associated with subsequent increases in productivity at surviving plants.

Our identification of a connection between falling trade costs and productivity growth at the industry level relates directly to research studying the impact of trade liberalization on macroeconomic growth. This research agenda often examines the connection between

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[1]Clerides et al. (1998), Bernard and Jensen (1999), Bernard and Wagner (1997), and Aw et al. (2000), for example, find that firm productivity growth is not improved after entry into exporting.

cross-country data and various proxies for openness, e.g., trade as a share of GDP. Though several studies, including Ben-David (1993), Sachs and Warner (1995), Edwards (1998) and Proudman and Redding (1998), offer evidence of a positive correlation between openness and growth, the robustness of this evidence has been challenged, most notably by Rodriguez and Rodrik (2000). In this paper, we make use of more direct measures of trade liberalization and link them to the responses of individual plants within industries. Our results suggest that *changes* in openness over time matter for the evolution of productivity.

Our focus on the microeconomic connection between trade policy and the gains from trade, i.e., between changes in trade costs and plant-level outcomes, builds upon a rich empirical literature recently surveyed by Tybout (2003).[2] The general consensus of this literature is that foreign competition both reduces the domestic market share of import-competing firms and reallocates domestic market share from inefficient to efficient firms. Our contribution to this literature is threefold. First, we make use of explicit measures of trade costs to demonstrate that this reallocation is driven by plant death and entry into exporting. Second we examine many dimensions of adjustment in a single study using a single dataset. Finally, we are the first to study the United States.[3]

The remainder of the paper is organized as follows: the next section assembles the predictions from the theoretical models on the responses to lower trade costs. Section 3 summarizes our dataset and describes how we construct our measure of trade costs. Section 4 presents the empirical results. Section 5 concludes.

2. Theory: heterogeneous firms and trade

The empirical approach of this paper is guided by theoretical work on the role of firms in international trade. Recent papers by Bernard et al. (2003) and Melitz (2003) develop firm-level models of intra-industry trade that are designed to match a set of stylized facts about exporting firms. These facts reveal that relatively few firms export and that exporters are more productive, larger, and more likely to survive than non-exporting firms (Bernard and Jensen, 1995). An important contribution of the models is their demonstration that such differences can arise even if exporting does not itself enhance productivity, a robust empirical finding (Clerides et al., 1998; Bernard and Jensen, 1999; Bernard and Wagner, 1997; Aw et al., 2000).

In each model, exporter superiority is shown to be the equilibrium outcome of more productive firms self-selecting into the export market. This selection is driven by the existence of trade costs, which only the most productive firms can absorb while still remaining profitable. Both papers relate reductions in trade costs to increases in aggregate industry productivity: as trade costs fall, lower productivity, non-exporting firms die, more productive non-exporters enter the export market, and the level of exports sold by the most

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[2]Many of these studies focus on developing countries: Tybout et al. (1991) and Pavcnik (2002) on Chile; Hay (2001) and Muendler (2004) on Brazil; Harrison (1996) on Cote d'Ivoire; Tybout and Westbrook (1995) on Mexico; Fernandes (2003) on Colombia; and Krishna and Mitra (1998) on India. Head and Ries (1999) and Trefler (2004) have examined the impact of trade liberalization on Canada.

[3]Our findings are consistent with studies examining the effects of changes to particular trading regimes in developed economies. Head and Ries (1999) and Trefler (2004), for example, find that the Canada–U.S. Free Trade Agreement induced substantial rationalization of production and employment. Our results provide evidence on the firm-level nature of such within-industry rationalization as trade costs fall.

productive firms increases. In this section, we summarize the foundation and intuition of these implications before taking them to a panel of plant-level data.

Melitz (2003) builds a dynamic industry model with heterogeneous firms producing a horizontally differentiated good with a single factor. The coexistence of firms with different productivity levels in equilibrium is the result of uncertainty about productivity before an irreversible entry decision is made. Entry into the export market is also costly, but the decision to export occurs after firms observe their productivity. Firms produce a unique horizontal variety for the domestic market if their productivity is above some threshold, and export to a foreign market if their productivity is above a higher threshold. Melitz (2003) restricts the analysis to countries with symmetric attributes to focus solely on the relationship between trade costs and firm performance.

In equilibrium, a decline in variable trade costs causes a reallocation of production across firms leading to higher industry productivity (Hypothesis 1). Falling trade costs mean greater profits for exporters, which are also the most productive firms, because of their increased access to external markets and lower per unit costs net of trade. Higher export profits pull higher productivity firms from the competitive fringe into the market, raising the productivity threshold for *market* entry and forcing the least productive non-exporters to shut down (Hypothesis 2). Higher export profits reduce the productivity threshold for *exporting*, increasing the number of firms which export, and increase the value of exports at current exporters (Hypothesis 3 and 4). In addition, declining trade costs invite more foreign varieties into the market and reduce the domestic sales of all domestic firms (Hypothesis 5).

Bernard et al. (2003) construct a static Ricardian model of heterogeneous firms, imperfect (Bertrand) competition with incomplete markups, and international trade. Firms use identical bundles of inputs to produce differentiated products under monopolistic competition. Within a country without trade, only the most efficient producer actually supplies the domestic market for a given product.

With international trade and variable trade costs, a firm produces for the home market if it is the most efficient domestic producer of a particular variety *and* if no foreign producer is a lower cost supplier net of trade costs. A domestic firm will export if it produces for the domestic market and if, net of trade costs, it is the low-cost producer for a foreign market. With positive trade costs, exporters are firms with higher than average productivity. Bernard et al. (2003) demonstrate that as trade costs fall, aggregate productivity rises (Hypothesis 1) because high-productivity plants are more likely to expand (Hypotheses 3 and 4) at the expense of low-productivity firms which fail (Hypothesis 2).[4]

Although varying in structure, each of the papers agree on the following testable hypotheses:

Hypothesis 1. A decrease in variable trade costs leads to an aggregate industry productivity gain.

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[4]Declining trade costs force low-productivity plants to exit the market in both Bernard et al. (2003) and Melitz (2003), but the mechanism by which this occurs differs subtly. In Bernard et al. (2003), low-productivity plants exit because of increased import competition from foreign varieties. In Melitz (2003), countries' varieties do not overlap. As a result, an increase in imports raises the probability of death at all levels of productivity while the death of low-productivity plants is actually driven by the entry into exporting of other domestic firms. In our empirical work while we use trade costs for imports, we are not able to distinguish between these two competing sources of plant deaths.

Hypothesis 2. A decrease in variable trade costs raises the probability of firm exit.

Hypothesis 3. A decrease in variable trade costs increases the number of exporting firms; new exporters are drawn from the most productive non-exporters (or new entrants).

Hypothesis 4. A decrease in variable trade costs increases export sales at existing exporters.

Hypothesis 5. A decrease in variable trade costs reduces the domestic market share (and domestic revenue) of surviving firms.

By assumption, these models of trade and heterogeneous firms do not allow any feedback between exporting and plant productivity and in both cases do not allow plant-level productivity to vary over time. As mentioned earlier, this assumption is based on a body of empirical work that shows no effect of exporting on plant productivity. However, to date there has been little empirical work on the effects of trade cost reductions on plant productivity growth.[5] In our empirical work, we consider an additional hypothesis regarding the possibility that within-plant productivity might respond to reduced trade costs, even when exporting itself is not associated with increased productivity growth:

Hypothesis 6. A decrease in variable trade costs increases plant-level productivity.

There are at least two possible reasons that plant productivity could increase in the face of lower trade costs. One is that increased competition may induce plants to improve their productive efficiency, the so-called 'kick in the pants' effect (Lawrence, 2000). Another is that the plant itself may change its product mix, i.e., intra-plant reallocation. Evidence for this type of switching by plants is found by Bernard et al. (2006a).

3. Data

3.1. U.S. manufacturing plants across industries and time

U.S. manufacturing plant data are drawn from the censuses of manufactures (CM) of the longitudinal research database (LRD) of the U.S. Bureau of the Census starting in 1987 and conducted every fifth year through 1997. Though CM data are available for earlier periods, we cannot use them in this study because comprehensive collection of export information did not begin until 1987. 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 and output. Plant output is recorded at the four-digit standard industrial classification level (SIC4). Details of the construction of the variables can be found in the Appendix.

The samples used in our econometric work below incorporate several modifications to the basic data. First, we exclude small plants (so-called administrative records) due to a lack of information on exports. Second, we drop plants in any 'not elsewhere classified' industries, i.e. four-digit SIC industries ending in '9'. These modifications leave us with two panels of approximately 210,000 plant-year observations in 337 manufacturing industries.

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[5]Pavcnik (2002) finds that within-plant productivity growth is higher in import-competing sectors after a liberalization in Chile. MacDonald (1994) find that import competition leads to large increases in labor productivity growth in highly concentrated industries and Lawrence (2000) reports a small positive effect of international competition on industry TFP growth especially for low-skill intensive industries.

3.2. Trade costs across industries and time

An important contribution of our analysis is the creation of a new set of industry-level trade costs. To most closely match the notion of trade costs in the theoretical models, we construct ad valorem trade costs that vary over time and across industries.[6]

We define variable trade costs for industry i in year t ($Cost_{it}$) as the sum of ad valorem duty (d_{it}) and ad valorem freight and insurance (f_{it}) rates, $Cost_{it} = d_{it} + f_{it}$. We compute d_{it} and f_{it} from underlying product-level U.S. import data complied by Feenstra (1996). The rate for industry i is the weighted average rate across all products in i, using the import values from all source countries as weights.[7] The ad valorem duty rate is therefore duties collected ($duties_{it}$) relative to the free-on-board customs value of imports (fob_{it}),

$$d_{it} = \frac{duties_{it}}{fob_{it}}.$$

Similarly, the ad valorem freight rate is the markup of the cost-insurance-freight value (cif_{it}) over fob_{it} relative to fob_{it},

$$f_{it} = \frac{cif_{it}}{fob_{it}} - 1.$$

We define the change in trade costs for census year t as the annualized change in tariff and freight costs over the preceding five years,

$$\Delta Cost_{it-5} = \frac{Cost_{it} - Cost_{i,t-5}}{5} = \frac{[d_{it} + f_{it}] - [d_{i,t-5} + f_{i,t-5}]}{5}. \tag{1}$$

In the empirical work below, we relate changes in trade costs between years $t-5$ to t ($\Delta Cost_i^{t-5:t}$) to plant survival, plant export decisions, changes in the plant exports, changes in plant domestic market share, and changes in plant multi-factor productivity between t to $t+5$. The five-year spacing between time periods corresponds to the interval between Censuses.

Table 1 reports average tariff, freight and total trade costs across two-digit SIC (SIC2) industries for five-year intervals from 1982–1997 using the import values of underlying four-digit SIC industries as weights. Costs are averaged over the five years preceding the year at the top of the column. Table 1 reveals that ad valorem tariff rates vary substantially and are highest in labor-intensive apparel and lowest in capital-intensive paper. Tariff rates decline across a broad range of industries over time. Indeed, over the entire period, tariffs decline by more than one quarter in 13 of 20 industries. The pace of tariff declines, however, varies substantially across industries.[8] Freight costs are highest among industries producing goods with a low value-to-weight ratio, including stone, lumber, furniture, and food. Freight costs also generally decline with time, though the pattern of declines is decidedly more mixed than it is with tariffs.

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[6]Unfortunately it is not possible to construct plant-specific trade cost measures.

[7]We use the concordance provided by Feenstra et al. (2002) to match products to four-digit SIC industries.

[8]The median percentage point reduction in product-level ad valorem tariff rates between 1989 and 1997 is 0.6%. Twenty five percent of products experience reductions greater than 1.5 percentage points. These differences do not account for changes in product codes during this interval or for changes in the non-ad valorem component of tariffs, which varies across industries (Irwin, 1998). A similar change cannot be computed for a longer interval because a change in the coding of imports in 1989 precludes direct product comparison with years after 1989.

Table 1
Ad valorem trade costs by two-digit SIC industry and year

Two-digit SIC industry	Tariff rate (d_{it}) (%)			Freight rate (f_{it}) (%)			Total rate ($d_{it} + f_{it}$) (%)		
	1982	1987	1992	1982	1987	1992	1982	1987	1992
20 Food	5.7	5.1	4.4	10.2	9.7	8.9	15.9	14.8	13.4
21 Tobacco	10.4	14.1	16.7	5.9	5.2	2.9	16.3	19.3	19.5
22 Textile	17.0	13.2	11.2	6.0	6.4	5.4	23.1	19.6	16.6
23 Apparel	23.3	20.7	16.9	8.6	7.6	6.3	31.8	28.3	23.2
24 Lumber	3.2	2.3	1.7	11.1	6.5	7.5	14.2	8.8	9.2
25 Furniture	5.9	4.1	4.1	9.4	8.6	8.5	15.3	12.8	12.6
26 Paper	0.9	0.8	0.6	3.9	3.1	4.4	4.7	4.0	4.9
27 Printing	1.7	1.2	1.1	5.9	5.5	5.1	7.5	6.6	6.2
28 Chemicals	3.8	4.3	4.4	6.4	4.8	4.5	10.1	9.1	9.0
29 Petroleum	0.4	0.5	0.9	5.2	5.1	8.3	5.6	5.5	9.3
30 Rubber	7.4	7.9	11.3	7.5	6.8	6.9	14.9	14.7	18.2
31 Leather	9.0	10.7	11.2	8.3	7.2	5.5	17.3	17.8	16.7
32 Stone	8.9	6.4	6.5	12.0	11.1	9.6	20.9	17.5	16.1
33 Primary metal	4.6	3.8	3.4	6.9	6.3	6.0	11.5	10.1	9.4
34 Fabricated metal	6.6	5.1	4.3	6.8	5.9	5.0	13.4	11.0	9.3
35 Industrial machinery	4.2	3.9	2.4	4.0	4.0	2.9	8.2	7.9	5.3
36 Electronic	5.0	4.6	3.3	3.4	3.1	2.4	8.3	7.6	5.6
37 Transportation	1.9	1.6	2.3	4.5	2.5	3.1	6.4	4.1	5.4
38 Instruments	6.8	5.2	4.3	2.7	2.8	2.5	9.5	8.0	6.8
39 Miscellaneous	9.6	5.7	5.2	5.0	4.9	3.6	14.6	10.6	8.8
Average	4.8	4.4	4.2	5.6	4.4	4.1	10.4	8.8	8.3

Notes: Table summarizes ad valorem tariff, freight and total trade costs across two-digit SIC industries. Costs for each two-digit industry are weighted averages of the underlying four-digit industries employed in our empirical analysis, using U.S. import values as weights. Figures for each year are the average for the five years preceding the year noted (e.g., the costs for 1982 are the average of costs from 1977 to 1981). The final row is the weighted average of all manufacturing industries included in our analysis.

Four-digit industries have even greater dispersion in trade cost changes. The average four-digit SIC industry saw trade costs fall 0.19 percentage points per year from 1982 to 1992.[9] Of the 337 four-digit SIC industries, we find that 82% experienced declines in tariff rates from 1982 to 1987, while 53% experienced declines from 1987 to 1992. For freight costs, 44% of the industries experienced declines from 1982 to 1987, while 66% experienced declines from 1987 to 1992.[10] In terms of overall trade costs, 79% of four-digit SIC industries saw trade costs decline between 1982 and 1987, while 62% had declining trade costs between 1987 and 1992.

In addition to being a good match to the theory, the trade costs constructed here have several advantages. First, they are the first to incorporate information about both trade policy and transportation costs. Second, they vary across industries and time. Finally, they are derived directly from product-level trade data collected at the border.

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[9]Data on the tariff and freight measures for all 337 (SIC4) industries and years is available at http://www.som.yale.edu/faculty/pks4/sub_international.htm.

[10]Using a different methodology, Hummels (1999) reports a similar decline in aggregate freight costs during the same period.

Even with these advantages, several caveats should be noted. First, the change in trade costs that we report are effective changes for a given industry; changes in the composition of products or importers within industries can induce variation in d_{it} and f_{it} even if actual statutory tariffs and market transportation costs remain constant.[11] A second caveat is that our trade cost measure is constructed only from U.S. import data. The theoretical models described above contemplate symmetric reductions in trade costs across countries, i.e., both outbound and inbound costs changes in the same way. To the extent that changes in U.S. trade policy or inbound transportation rates diverge from those in other countries, measured changes in trade costs may over- or underestimate the changes implemented by other countries. This problem is likely to be more severe for trade policy than for transportation rates. Unfortunately, because disaggregate tariff rates and freight costs are unavailable for U.S. export destinations during the period in question, we cannot construct a direct measure of outbound trade costs.[12] However, these problems should reduce the possibility that we find an export response. Finally, our measure of trade costs does not include non-tariff barriers (NTBs) such as quotas or regulatory requirements. NTBs are an important source of trade distortions but there is no available industry-level data for our sample period.

We now examine the effect of changing trade costs on plant survival, export entry and growth, and productivity growth.

4. Empirical results

In this section, we examine the relationships between trade costs and industry- and plant-level outcomes described in Section 2.

4.1. Industry productivity growth

The most important implication of both models presented above is that lower trade costs increase aggregate productivity (Hypothesis 1). We estimate a simple regression of the five-year change in four-digit SIC industry productivity on the decline in industry trade costs in the previous five years,

$$\Delta TFP_{it} = c_t + \beta^1 \Delta Cost_{it-5} + \delta_i + \delta_t + \varepsilon_{it}, \tag{2}$$

where ΔTFP_{it} is the average annual percent change in industry total factor productivity from year t to year $t + 5$, $\Delta Cost_{it-5}$ is the annualized percent change in total trade costs between years $t - 5$ and t, and δ_i and δ_t are sets of industry and year fixed effects. Data for

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[11]In theory one could avoid this problem by aggregating changes in product trade costs rather than aggregating levels of product trade costs up to SIC4 industries. However, in practice such a procedure encounters a number of problems. Most importantly, the United States changed import product categorization systems between 1988 and 1989, i.e., in the middle of our sample. In addition, the set of countries importing a given product varies substantially from year to year, yielding numerous zeros for product-level tariff changes.

[12]To check the appropriateness of using import data for both inward and outward U.S. trade costs, we compare U.S. and European Union tariffs changes across industries from 1992 to 1997 (after the end of our sample) using the TRAINS database compiled by the United Nations Conference on Trade and Development. TRAINS data is unavailable for our sample period. This database tracks product-level tariffs for a limited, but growing, set of countries starting in 1990. Using these data, we find that the correlation of United States and European Union ad valorem tariff rate changes across SIC4 industries is positive and significant at the 1% level. This correlation indicates that the inward and outward tariffs are moving in the same direction across industries.

Table 2
Industry productive growth, 1982–1997

Regressor	Change in TFP	Change in TFP
Change in trade cost	−0.152[*]	−0.190[*]
	(0.079)	(0.104)
Year fixed effects	Yes	Yes
Industry fixed effects	No	Yes
Observations	1,153	1,153
R^2	0.00	0.02

Notes: Industry-level OLS regression results. Robust standard errors adjusted for clustering at the four-digit SIC level are in parentheses. Industry fixed effects are for two-digit SICs. Dependent variable is the average annualized change in Bartelsman et al. (2000) five-factor total factor productivity from years $t + 1$ to $t + 5$. Regressor is the change in total trade costs between years $t − 5$ and t. Regressions cover 1972–1996. Coefficients for the regression constant and dummy variables are suppressed.
*** Significant at the 1% level;
** Significant at the 5% level;
* Significant at the 10% level.

five-factor industry total factor productivity are drawn from Bartelsman et al. (2000). Our use of prior changes in trade costs to predict subsequent behavior is helpful for two reasons. First, it biases the empirical work against Hypotheses 1–5 by excluding contemporaneous reallocation. Second, it helps to mitigate problems of endogeneity and omitted variables.

OLS regression results are reported in Table 2. The two columns of the table report results both with and without two-digit SIC industry fixed effects. Both columns display robust standard errors adjusted for clustering at the four-digit SIC industry. Results in both columns are consistent with the heterogeneous-firm models: the negative coefficients indicate that falling trade costs are followed by more rapid industry productivity growth. In both cases the coefficients are significant at the 10% level. The magnitude of the estimates suggest that a one standard deviation (within industry) decline in trade costs is associated with an increase of productivity growth of 0.2 percentage points per year.

4.2. Plant deaths

To examine the potential reallocative effects of changing trade costs, we start by estimating the impact on plant survival (Hypothesis 2) via a logistic regression. We report results for a base specification (also used in all subsequent estimations), which includes only the measure of changing trade costs on the right-hand side of the regression, as well as two variants. The probability of death for a plant in industry i between year t and year $t + 5$ is given by

$$(\text{base}) \Pr(D_{pt+5} = 1) = \Phi(\beta \Delta Cost_{it-5} + \delta_i + \delta_t),$$
$$(\text{variant 1}) \Pr(D_{pt+5} = 1) = \Phi(\beta \Delta Cost_{it-5} + \gamma X_{pt} + \delta_i + \delta_t),$$
$$(\text{variant 2}) \Pr(D_{pt+5} = 1) = \Phi(\beta \Delta Cost_{it-5} + \gamma X_{pt} + \theta \Delta Cost_{it-5} \cdot Z_{pt} + \delta_i + \delta_t), \quad (3)$$

where $\Delta Cost_{it-5}$ is the annual average change in industry trade costs in the preceding five years, X_{pt} is a vector of plant characteristics, Z_{pt} is a subset of the vector of plant characteristics interacted with the trade cost measure, and δ_i and δ_t are sets of industry and time dummies.

The first variant adds a number of plant characteristics to the base specification. We include measures of plant productivity, size and age as all of these have been found to influence plant survival in numerous studies starting with Dunne et al. (1989).[13] In addition, we include controls for plant capital intensity, the wage level, export status and a multiproduct indicator as recent work finds that all these plant attributes improve survival chances (Bernard and Jensen, 2006). Finally, we include two measures of the structure of the firm, indicators for multiplant status and multinational ownership, that have been shown to reduce the chances of survival at individual plants (Bernard and Jensen, 2006).

The final variant adds interactions of trade costs with plant productivity, export status and multinational status to check whether responses to changes in trade costs vary across plants of differing productivity and levels of international engagement. Results are reported with year and two-digit SIC industry fixed effects and standard errors are clustered at the four-digit industry level. Since all the plant-level empirical specifications include industry fixed effects, the implicit null hypothesis is that deviations from the average industry change in trade costs are correlated with plant outcomes.

Table 3 reports the regression results. The first column focuses only on the trade cost variable of interest. It indicates that plant death and changing trade costs have the predicted negative association: as trade costs fall, plant death is more likely. The change in trade cost measure is significant at the 10% level.

The second column of the table adds in plant characteristics as well as multiplant and multinational dummies while the third column includes interactions of the trade cost measure with relative productivity, export status and the multinational indicator. In both cases, changes in trade costs remain negatively and statistically significantly related to plant death. The magnitude of the trade cost coefficient is slightly greater with additional controls as is the level of significance. A one standard deviation decline in trade costs increases the probability of death by 1.3 percentage points or approximately 5%.

As implied by theory, relative productivity and export status are also negatively and statistically significantly associated with plant death in both column two and column three. The results in column three also reveal that only the interaction of trade costs and plant productivity is statistically significant. The sign of this interaction is, as expected, positive: the probability of death is relatively lower for high-productivity plants in the face of falling trade costs.

With respect to other plant characteristics, we find that larger, older and more capital-intensive firms are more likely to survive, as are plants that pay higher wages or produce multiple products. For plants that are part of a large, multi plant or multinational firm, the probability of death conditional on other plant characteristics is higher.

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[13]To control for plant's productivity, we use the multifactor superlative index number of Caves et al. (1982) and construct percentage difference in plant productivity from that of the mean plant in the four-digit SIC industry in each year t (see Appendix).

Table 3
Probability of death, 1987–1997

Regressor	Logit plant death	Logit plant death	Logit plant death
Change in trade cost	−5.664[*]	−6.388[**]	−6.669[**]
	(3.148)	(2.782)	(2.937)
Relative productivity × change in trade cost		−0.221[***]	−0.202[***]
		(0.059)	(0.053)
			12.178[**]
			(6.012)
Exporter × change in trade cost		−0.403[***]	−0.398[***]
		(0.033)	(0.033)
			4.179
			(3.637)
US MNC × change in trade cost		0.256[***]	0.249[***]
		(0.051)	(0.051)
			−3.823
			(3.805)
Log(employment)		−0.263[***]	−0.264[***]
		(0.012)	(0.012)
Age		−0.020[***]	−0.020[***]
		(0.001)	(0.001)
Log(K/L)		−0.095[***]	−0.093[***]
		(0.020)	(0.019)
Log(wage)		−0.309[***]	−0.308[***]
		(0.046)	(0.047)
Part of multi plant firm		0.282[***]	0.282[***]
		(0.063)	(0.062)
Producer of multiple products		−0.320[***]	−0.318[***]
		(0.034)	(0.033)
Industry fixed effects	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes
Observations	210,664	210,664	210,664
Log likelihood	−115,329	−109,734	−109,713

Notes: Plant-level logistic regression results. Robust standard errors adjusted for clustering at the four-digit SIC level are in parentheses. Industry fixed effects are for two-digit SICs. Dependent variable indicates plant death between years t and $t+5$. First regressor is the change in total trade costs between years $t-5$ and t. Regressions cover two panels: 1982–1987 and 1987–1992. Coefficients for the regression constant and dummy variables are suppressed.
*** Significant at the 1% level;
** Significant at the 5% level;
* Significant at the 10% level.

4.3. New exporters

While increasing failure probabilities are an important prediction of the heterogeneous-firm trade models, equally important for the reallocative process is the entry of new firms into exporting. We estimate the impact of falling trade costs on the probability that non-exporting plants become exporters (Hypothesis 3) via a logistic regression of export status on our measure of changing trade costs and plant relative productivity as well as an interaction of changing trade costs and plant productivity. These regressions

Table 4
Probability of entering the export market, 1987–1997

Regressor	Logit export next	Logit export next	Logit export next
Change in trade cost	−8.933[*]	−8.621[*]	−8.223[*]
	(5.018)	(5.033)	(4.947)
Relative productivity × change in trade cost		0.191[***]	0.337[***]
		(0.054)	(0.084)
		−1.121	1.359
		(3.922)	(4.532)
Log(employment)			0.557[***]
			(0.024)
Age			−0.009[***]
			(0.002)
Log(K/L)			0.141[***]
			(0.041)
Log(wage)			0.339[***]
			(0.078)
Part of multi plant firm			−0.076
			(0.050)
Producer of multiple products			0.019
			(0.037)
Industry fixed effects	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes
Observations	124,019	124,019	124,019
Log likelihood	−41,874	−41,846	−39,309

Notes: Plant-level logistic regression results. Robust standard errors adjusted for clustering at the four-digit SIC level are in parentheses. Industry fixed effects are for two-digit SICs. Dependent variable indicates whether a non-exporting plant in 1987 becomes an exporter between the 1987 and 1992 Censuses. First regressor is the change in total trade costs between years $t-5$ and t. Regressions cover two panels: 1982–1987 and 1987–1992. Coefficients for the regression constant and dummy variables are suppressed.
*** Significant at the 1% level;
** Significant at the 5% level;
* Significant at the 10% level.

are given by

$$\text{(base)}\ \Pr(E_{pt+5} = 1) = \Phi(\beta \Delta Cost_{it-5} + \delta_i + \delta_t),$$
$$\text{(v1)}\ \Pr(E_{pt+5} = 1) = \Phi(\beta \Delta Cost_{it-5} + \gamma PR_{pt} + \theta \Delta Cost_{it-5} \cdot PR_{pt} + \delta_i + \delta_t),$$
$$\text{(v2)}\ \Pr(E_{pt+5} = 1) = \Phi(\beta \Delta Cost_{it-5} + \gamma PR_{pt} + \theta \Delta Cost_{it-5} \cdot PR_{pt} + \lambda Z_{pt} + \delta_i + \delta_t),$$

$$(4)$$

where PR_{pt} is the measure of plant relative productivity and Z_{pt} is a set of additional plant characteristics. Additional plant controls include size, age, capital intensity, wage level, and multiproduct and multiplant dummies.[14] As in the previous section, we include year and industry fixed effects and cluster the standard errors at the industry level.

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[14]The literature on entry into exporting, e.g., Roberts and Tybout (1997) and Bernard and Jensen (2004), emphasizes the role of sunk costs inducing hysteresis and unobserved plant attributes. Given the limited nature of our panel, we are unable to control for such effects and instead focus on the entry behavior of non-exporting plants.

Results are reported across three columns in Table 4, with the first column focusing on our trade cost measure and subsequent columns including additional plant characteristics. In all three columns, we find a negative and statistically significant association between changes in trade costs and the probability that non-exporting plants become exporters across Census years. The probability of becoming an exporter is higher in industries with greater declines in trade costs. In each case the trade cost measure is significant at the 10% level

In columns two and three, we find, as expected, a positive association between plants' relative productivity and their entry into exporting. This finding matches results from a substantial body of research on selection into export markets, i.e., more productive non-exporters become exporters (see Bernard and Jensen, 1995, 1999). The interaction between plant productivity and the change in trade costs is not statistically significant and changes sign between columns two and three, suggesting that the selection effect is not more pronounced during periods of declining trade costs. Finally, we find that larger, younger and more capital-intensive firms are more likely to become exporters, as are plants that pay higher wages.

The magnitude of the effect of falling trade costs is substantial. For a non-exporter with average productivity, a one standard deviation reduction in trade costs increases the probability of exporting by 0.6%. The average probability of becoming an exporter in the sample is 7.2%.

These results, coupled with the increased probability of death as trade costs fall, offer support for the two major predictions of the heterogeneous-firm models. In particular, they highlight the heterogeneity of outcomes across plants that vary in terms of their export status and labor productivity. In response to falling trade costs, some plants, typically low-productivity non-exporters, are more likely to die, while higher-productivity non-exporters take advantage of the lower trade costs and begin exporting.

4.4. Export growth

We estimate the impact of falling trade costs on plants' export growth (Hypothesis 4) via an OLS regression of the log difference in exports across Census years, $\ln(Exports_{p,t+5}) - \ln(Exports_{pt})$, on plant characteristics,

$$(\text{base})\Delta_{t:t+5}\ln(Exports_p) = \beta\Delta Cost_{it-5} + \delta_i + \delta_t + \epsilon_{pit},$$

$$(\text{v1})\Delta_{t:t+5}\ln(Exports_p) = \beta\Delta Cost_{it-5} + \gamma X_{pt} + \delta_i + \delta_t + \epsilon_{pit},$$

$$(\text{v2})\Delta_{t:t+5}\ln(Exports_p) = \beta\Delta Cost_{it-5} + \gamma X_{pt} + \theta\Delta Cost_{it-5} \cdot Z_{pt} + \delta_i + \delta_t + \epsilon_{pit}, \quad (5)$$

where the variables are defined as above. The relatively small number of observations in the regression in this section is driven by its focus on the relatively few plants that export in two consecutive census years. As above, our regressions include year and industry fixed effects and standard errors are clustered at the industry level.

Results for three specifications with an increasing number of regressors are reported in the three columns of Table 5. Each column reports a negative and statistically significant relationship between changes in trade costs and changes in exports: plants in industries with relatively greater declines in trade costs experience larger growth in exports. Additional results in Table 5 indicate no statistically significant relationship between export growth and relative plant productivity. However, we do find that exporter size, age

Table 5
Change in log exports, 1987–1997

Regressor	OLS export growth	OLS export growth	OLS export growth
Change in trade cost	−8.623[**]	−8.829[**]	−9.203[***]
	(3.495)	(3.532)	(3.541)
Relative productivity × change in trade cost		−0.027	−0.029
		(0.048)	(0.050)
			−1.652
			(6.088)
US MNC × change in trade cost		0.001	0.004
		(0.033)	(0.033)
			2.077
			(4.246)
Log(employment)		−0.041[***]	−0.041[***]
		(0.011)	(0.011)
Age		−0.008[***]	−0.008[***]
		(0.001)	(0.001)
Log(K/L)		0.009	0.009
		(0.017)	(0.017)
Log(wage)		0.022	0.022
		(0.044)	(0.044)
Part of multi plant firm		−0.066[**]	−0.066[**]
		(0.029)	(0.029)
Producer of multiple products		−0.028	−0.028
		(0.026)	(0.026)
Industry fixed effects	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes
Observations	22,091	22,091	22,091
R^2	0.03	0.03	0.03

Notes: Plant-level OLS regression results. Robust standard errors adjusted for clustering at the four-digit SIC level are in parentheses. Industry fixed effects are for two-digit SICs. Dependent variable is the difference in plants' log exports between years t and $t + 5$. First regressor is the change in total trade costs between years $t − 5$ and t. Regressions cover two panels: 1982–1987 and 1987–1992. Coefficients for the regression constant and dummy variables are suppressed.
*** Significant at the 1% level;
** Significant at the 5% level;
* Significant at the 10% level.

and status as part of a multiple plant firm are negatively and significantly associated with export growth.

4.5. Domestic market share

The heterogeneous-firm models offer a variety of predictions about output and employment growth across plants as trade costs decline. Melitz (2003) contains the clearest prediction, i.e., that domestic market share should fall for all surviving plants (and, of course, for plants that close). We test this hypothesis (H5) by considering how surviving plants' changes in market share from t to $t + 5$ vary according to trade costs and firm

characteristics,

$$(base)\Delta_{t:t+5}Share_p = \beta\Delta Cost_{it-5} + \delta_i + \delta_t + \epsilon_{pit},$$
$$(v1)\Delta_{t:t+5}Share_p = \beta\Delta Cost_{it-5} + \gamma X_{pt} + \delta_i + \delta_t + \epsilon_{pit},$$
$$(v2)\Delta_{t:t+5}Share_p = \beta\Delta Cost_{it-5} + \gamma X_{pt} + \theta\Delta Cost_{it-5} \cdot Z_{pt} + \delta_i + \delta_t + \epsilon_{pit}, \qquad (6)$$

where $Share_{pt}$ represents plant p's domestic sales in its industry as a share of total domestic sales plus imports in that industry and the other variables are defined as above.[15]

Results for the three different specifications are reported in Table 6. In contrast with the predictions of the heterogeneous-firm models, changes in industry-level trade costs are uncorrelated with changes in plant-level domestic market share in all specifications. On the other hand, results in the final column of the table reveal that the most productive firms as well as exporters lose market share when trade costs fall, although the magnitude of the losses are small. In response to a one standard deviation decline in trade costs, for example, the market share of the typical exporter would fall by 0.005%. This lack of response of domestic market share stands in contrast to the literature on developing countries which typically reports a fall in domestic sales in response to trade liberalization (see Tybout, 2000).

The absence of a substantial response of domestic market share by U.S. firms to falling trade costs suggests a role for other forces and perhaps a need for models exhibiting a richer set of predictions about the response of domestic output to international trade.

4.6. Changes in plant productivity

In this section we move beyond the predictions of the new heterogeneous-firm model and consider the possibility that changes in trade costs may influence plant productivity. To date the empirical literature has focused almost exclusively on whether there are positive productivity effects of exporting.[16] Our approach is broader in that we look at the link between trade cost reductions and productivity, rather than limiting ourselves to the role of exporting.

To examine the impact of falling trade costs on exporters' relative total factor productivity growth, we estimate OLS regressions of the change in exporters' relative productivity on our measure of trade costs and plant characteristics,

$$(base)\Delta_{t:t+5}TFP_p = \beta\Delta Cost_{it-5} + \delta_i + \delta_t,$$
$$(v1-2)\Delta_{t:t+5}TFP_p = \beta\Delta Cost_{it-5} + \gamma X_{pt} + \delta_i + \delta_t,$$
$$(v3-4)\Delta_{t:t+5}TFP_p = \beta\Delta Cost_{it-5} + \gamma X_{pt} + \theta\Delta Cost_{it-5} \cdot Z_{pt} + \delta_i + \delta_t, \qquad (7)$$

where the variables are defined as above. As in the previous section, regressions in this section include year and industry fixed effects, and standard errors are clustered at the industry level.

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[15]The use of domestic market share, rather than the change in domestic sales, accounts for differential growth at the industry level due to other factors.

[16]For the United States and other developed economies there is little evidence of feedback from exporting to plant productivity, for example, see Bernard and Jensen (1999) for the US and Bernard and Wagner (1997) for Germany. However, some studies have found evidence of a role for exporting to influence plant productivity, e.g., Van Biesebroeck (2005) (Africa), Aw et al. (2000) (some industries in Taiwan), Alvarez and Lopez (2005) (Chile), and Kraay (1999) (China).

Table 6
Change in domestic market share, 1987–1997

Regressor	OLS domestic market share	OLS domestic market share	OLS domestic market share
Change in trade cost	0.0008 (0.0035)	0.0004 (0.0037)	−0.0043 (0.0036)
Relative productivity × change in trade cost		−0.0008*** (0.0001)	−0.0007*** (0.0001)
			0.0162* (0.0088)
Exporter × change in trade cost		0.0001 (0.0001)	0.0001* (0.0001)
			0.028** (0.0115)
US MNC × change in trade cost		−0.0003** (0.0002)	−0.0003** (0.0001)
			−0.0145 (0.0246)
Log(employment)		−0.0001*** (0.0000)	−0.0001*** (0.0000)
Age		−0.00002*** (0.00000)	−0.00002*** (0.00000)
Log(K/L)		−0.00005 (0.00004)	−0.00005 (0.00004)
Log(wage)		0.0001 (0.0001)	0.0001 (0.0001)
Part of multi plant firm		0.00004 (0.0001)	0.00005 (0.0001)
Producer of multiple products		−0.0001 (0.0000)	−0.0001 (0.0000)
Industry fixed effects	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes
Observations	126,871	126,871	126,871
R^2	0.002	0.005	0.005

Notes: Plant-level OLS regression results. Robust standard errors adjusted for clustering at the four-digit SIC level are in parentheses. Industry fixed effects are for two-digit SICs. Dependent variable indicates change in plant domestic market share between years t and $t+5$. First regressor is the change in total trade costs between years $t-5$ and t. Regressions cover two panels: 1982–1987 and 1987–1992. Coefficients for the regression constant and dummy variables are suppressed.
*** Significant at the 1% level;
** Significant at the 5% level;
* Significant at the 10% level.

Results for five different specifications with an increasing number of regressors are reported in Table 7. Changes in industry-level trade costs are negatively associated with plant-level productivity growth in all specifications; however, these associations are statistically significant at the 10% level only after controlling for other plant attributes. Results in the second and third columns indicate that a *negative* and statistically significant relationship between exporting and productivity growth disappears once plants' period t

Table 7
Plant TFP growth, 1987–1997

Regressor	OLS TFP growth	OLS TFP growth	OLS TFP growth	OLS TFP growth	OLS TFP growth
Change in trade cost	−1.027	−1.494*	−1.902*	−1.924*	−2.321*
	(0.733)	(0.854)	(1.008)	(1.025)	(1.228)
Relative productivity × change in trade cost			−0.545***	−0.545***	−0.545***
			(0.016)	(0.016)	(0.016)
				0.559	0.545
				(1.389)	(1.360)
Exporter × change in trade cost		−0.143***	0.007	0.007	0.008
		(0.005)	(0.007)	(0.007)	(0.007)
					1.182
					(0.913)
US MNC × change in trade cost		−0.014*	0.021*	0.021*	0.022**
		(0.008)	(0.011)	(0.011)	(0.011)
					2.138**
					(1.012)
Log(employment)		−0.002	−0.013***	−0.013***	−0.013***
		(0.003)	(0.003)	(0.003)	(0.003)
Age		0.000	−0.001***	−0.001***	−0.001***
		(0.000)	(0.000)	(0.000)	(0.000)
Log(K/L)		0.150***	0.041***	0.041***	0.041***
		(0.009)	(0.006)	(0.006)	(0.006)
Log(wage)		−0.203***	0.028*	0.028*	0.028*
		(0.008)	(0.016)	(0.016)	(0.016)
Part of multi plant firm		−0.063***	−0.012	−0.012	−0.011
		(0.009)	(0.015)	(0.014)	(0.015)
Producer of multiple products		−0.015**	−0.019***	−0.019***	−0.019***
		(0.006)	(0.007)	(0.007)	(0.007)
Industry fixed effects	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes
Observations	119,918	119,918	119,918	119,918	119,918
R^2	0.01	0.11	0.26	0.26	0.26

Notes: Plant-level OLS regression results. Robust standard errors adjusted for clustering at the four-digit SIC level are in parentheses. Industry fixed effects are for two-digit SICs. Dependent variable indicates change in plant TFP between years t and $t + 5$. First regressor is the change in total trade costs between years $t − 5$ and t. Regressions cover two panels: 1982–1987 and 1987–1992. Coefficients for the regression constant and dummy variables are suppressed.
*** Significant at the 1% level;
** Significant at the 5% level;
* Significant at the 10% level.

total factor productivity is included as a control variable. Results in the last three columns indicate relatively higher productivity growth for U.S. multinationals. Interactions between our measure of changing trade costs and productivity, export status and multinational status are all positive (suggesting lower productivity growth for these types of firms in industries with falling trade costs) but only the multinational interaction is statistically significant.

5. Conclusions

This paper investigates several of the channels by which international trade is thought to enhance economies' efficiency. We find that greater exposure to international trade via declining trade costs promotes productivity gains at three levels: across industries within manufacturing, across plants within industries, and within plants. Our analysis is made possible by the construction of a unique new dataset that tracks average tariff and transportation costs across U.S. manufacturing industries from 1977 to 2001. By linking this dataset to the United States Census of Manufactures, we are able to examine the influence of falling trade costs on U.S. manufacturing industry and plant outcomes.

Our results are striking. First, we find that industries with relatively high reductions in tariff rates and transport costs exhibit relatively high gains in overall productivity growth. Second, we show that these aggregate gains are driven by a reallocation of activity toward more productive plants within industries. Falling trade costs increase the probability that low-productivity plants fail and raise the probability that higher-productivity plants expand by entering export markets or increasing their sales to foreign countries.

Finally, we provide the first comprehensive evidence of a relationship between trade liberalization and productivity growth within plants in a developed economy. One explanation for this link is that reducing trade barriers jump-starts productivity growth by giving previously protected firms a "kick in the pants" (Lawrence, 2000). Exactly how this productivity growth is achieved merits further inquiry. It may be that trade acts as a simple conduit for the transfer of technology between arm's length or related party firms. More broadly, it may occur via Schumpeterian incentives to invest in innovation, incentives to put some technological distance between one's own firm and one's competitors (Boone, 2000), or changes in the nature of the agency problem between owners and managers (e.g., Vousden and Neil, 1994). Another possibility is that the plant itself may be changing its product mix in response to falling trade costs, i.e., the type of intra-plant reallocation found by Bernard et al. (2006a). In this case it may be that the underlying productivity of manufacturing each good is unchanged but plant-level productivity is affected by the change in output mix.

Overall, the results presented in this paper provide support for recent theoretical models of international trade that emphasize the importance of heterogeneous firms and cross-firm reallocation for aggregate outcomes. However, they also suggest the need for further research on firm responses in their domestic markets and on the role of trade costs in shaping firm productivity. To date, the initial heterogeneous-firm models achieved analytical tractability by focusing on a single industry and factor of production. Recent theoretical research, e.g., Bernard et al. (2006b), has extended the scope of the heterogeneous-firm models to incorporate multiple sectors and factors of production and may yield additional insights into the role firms play in mediating alternate dimensions of economic performance, e.g., skill or capital deepening as well as the distributional consequences of globalization.

Appendix A. Data

The data in this paper come from the longitudinal research database (LRD) of the Bureau of the Census. We use data from the CM starting in 1987 and continuing 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.

A.1. Variables

Size—log of plant total employment.

Age—the difference between the current year and the first recorded census year for the plant, starting with the 1963 Census. Plants that are in their first census year are given an age of zero.

Capital intensity—the log of the capital–labor ratio, where capital is the book value of machinery, equipment, buildings and structures.

Wage—log of the average wage paid at the plant.

Non-production wage—log of the average wage paid to production workers at the plant.

Exporter—an indicator variable that is one when the plant exports and zero otherwise.

Multiproduct—the plant produces more than one product where a product is defined as a five digit 1987 SIC product-class.

Multiplant—the plant belongs to a firm with multiple plants.

Multinational—the plant belongs to a firm that is a multinational where multinational status is a function of the share of firm assets held overseas and is defined to be a U.S. firm with at least 10% of its assets held outside the United States in 1987.

Plant productivity—We estimate plant's total factor productivity using multi-factor superlative index number of Caves et al. (1982) extended by Good et al. (1997) and discussed in Aw et al. (2003). The productivity index is calculated separately for each of the four-digit SIC industries in the sample. It compares each plant in each year within an industry to a hypothetical reference plant that has the arithmetic mean values of log output, log input, and input cost shares over all plants in the industry in each year. Each plant's logarithmic output and input levels are measured relative to this reference point in each year and then the reference points are chain linked over time.

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