Trade Liberalization, Firm Heterogeneity, and Unemployment: An Empirical Investigation

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Abstract

This paper provides empirical evidence for the interaction between firm-level total factor productivity and trade liberalization as key determinants of firm-level job destruction caused by trade. We also test some key theoretical predictions from Melitz (2003), whose model is used to derive an explicit equation relating firm productivity and trade-induced labor layoff when a country liberalizes its trade policy. Employing US firm-level data, we find empirical support and quantify the following: a) Total factor firm productivity is inversely related to firm-level trade-induced layoffs; b) Trade liberalization increases the number of jobs lost due to trade; c) Trade liberalization results in an increase in the minimum level of productivity required for domestic production; d) Trade liberalization lowers the minimum productivity threshold required for exporting; e) The increase, due to trade liberalization, in the minimum productivity threshold for domestic production is smaller than the absolute decrease in the export productivity threshold.

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1 Introduction

Following Melitz (2003), a fast growing literature has been studying the consequences of heterogeneous firms on the effects of trade and trade liberalization. Many of these studies have clear structural predictions about the relationship between trade liberalization, and firm-level trade-induced labor layoffs when firms differ in their total factor productivity. Despite the interest in the role of heterogeneity, however, many of the theoretical implications and relationships of Melitz’s model regarding the labor market have not yet been tested empirically. In this paper, we make an attempt to narrow this gap by providing empirical evidence for the interaction between firm productivity, and trade liberalization in the determination of firm-level, trade-induced layoffs.

Melitz (2003) develops a dynamic industry model with heterogeneous firms to examine the intra-industry effects of international trade. He finds that opening to trade causes the least productive firms to stop producing and the more productive firms to start exporting, as only the more productive firms can bear the fixed trade costs. As a result, market shares are reallocated toward more productive firms, which leads to an aggregate productivity increase and an increase in the zero-profit productivity cutoff, defined as the minimum productivity level needed for a firm to produce domestically. Melitz also shows that trade liberalization results in an increase in zero-profit productivity cutoff and a decrease in the export productivity cutoff, defined as the minimum productivity level needed for a domestic firm to enjoy profitable exports.

Data limitations do not allow Melitz’s predictions to be tested directly. In particular, it is practically impossible to partition firms’ profits between their domestically generated portion and the part coming from exports. Our main contribution in this paper is that we are able to quantify the relationship between firm productivity and firm layoffs caused by trade. We do this by concentrating on the labor market and by employing reliable, novel data that allows us to directly identify firm-level, trade-induced labor layoffs. In addition,

we test and find support for important theoretical predictions regarding the direction and magnitude of the changes in the zero-profit productivity cutoff and the export productivity cutoff when a country liberalizes its trade policy.

We stay close to the original Melitz framework to derive a structural labor equation where the interactions between total factor firm productivity and trade liberalization are the key determinants of the number of workers laid off due to trade. We start by deriving firm-level employment in an autarky equilibrium. Then, we determine the equilibrium number of workers in each firm when the country opens up to costly trade and exercises protection. As a final step, we consider the case of trade liberalization, which is the basis for our empirical analysis. The theoretical predictions of our structural model, derived when a country liberalizes its trade policy, suggest that, all else equal: a) More productive firms will lay off fewer workers; b) The more a country opens up to trade, the more layoffs there will be in the firms that produce only for the domestic market; c) Firms in more protected industries will suffer fewer layoffs. The intuition behind these findings is also clear: lower trade costs give a competitive edge to the more productive firms that can afford to cover the export entry cost. These firms compete for resources with the less productive domestically producing firms, which forces some of the latter to exit the market and leads to an increase in the zero profit productivity cutoff. In addition, all remaining firms that produce only for the domestic market suffer market share and sales losses, which are accompanied by layoffs.2

To test the predictions of our theoretical labor equation empirically, we use US firm-level data for the period 1980-2005. We adopt the methodology from Petrin and Levinsohn (2003) and Olley and Pakes (1996) to calculate two different total factor firm productivity measures, and we employ the Petition for Trade Adjustment Assistance Dataset, maintained by the Employment and Training Administration of the U.S. Department of Labor, to identify directly the number of workers laid-off due to trade at the firm level. We find strong empirical support for the structural predictions of our model as well as for some theoretical implications from other studies. Our results indicate that firm productivity,

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2It should be emphasized that we derive firm-specific predictions on employment, that depend on the range of firms active in the sector. In other words, we compute firm-specific employment, an intensive metric, accounting for the extensive dynamics within each sector.
trade liberalization, and the interactions between them are indeed key determinants of the magnitude of firm-level job destruction. More specifically, we find that a one percent increase in a firm’s total factor firm productivity above the average for a sector saves between 120 and 1990 jobs, depending on the industry, that would be lost due to trade liberalization, while, on average, an additional one percent of trade liberalization increases the number firm-level, trade-induced layoffs by 6%. In addition, we provide empirical support for the following theoretical predictions from Melitz (2003): a) Trade liberalization results in a higher zero-profit productivity cutoff and a lower export productivity cutoff for domestic firms; b) The increase in the zero-profit productivity cutoff for domestic production is smaller than the absolute decrease in the export productivity cutoff.

The remainder of the paper is structured as follows. Section 2 presents the theoretical model. Section 3 presents the econometric model, data description, estimation, empirical results, and sensitivity analysis. Section 4 concludes.

2 Theoretical Setting

Our theoretical model follows Melitz (2003). Given our empirical strategy, however, we concentrate on the labor market and analyze the effects of trade and trade liberalization on the equilibrium number of workers employed by each firm.

2.1 Autarky Equilibrium

Consumption. The representative consumer’s utility is derived from consumption of a continuum of goods indexed by $\omega$, and takes a CES functional form:

$$U = \left[ \int_{\omega \in \Omega} q(\omega)^{\sigma} d\omega \right]^{\frac{1}{\sigma}},$$

where $q(\omega)$ is the amount of variety $\omega$ consumed, $\Omega$ is the mass of potentially available goods, and $\sigma = 1/(1-\rho) > 1$ is the elasticity of substitution between different varieties. The consumer’s utility can be considered as an aggregate good, $Q \equiv U$, which is composed of dif-
ferent goods varieties, with a corresponding aggregate price index \( P = \left[ \int_{\omega \in \Omega} p(\omega)^{1-\sigma} d\omega \right]^{\frac{1}{1-\sigma}}. \)

Making use of the definitions of aggregate consumption and the CES price index, we solve the representative consumer’s problem to derive demand, \( q(\omega) \), and expenditure, \( r(\omega) \), for each individual variety:

\[
q(\omega) = Q \left[ \frac{p(\omega)}{P} \right]^{-\sigma}, \quad r(\omega) = R \left[ \frac{p(\omega)}{P} \right]^{1-\sigma},
\]

(2.1)

where \( R = PQ = \int_{\omega \in \Omega} r(\omega) d\omega \) denotes aggregate expenditure.

**Production.** There is a continuum of firms, and each of them produces a different variety \( \omega \).

Production requires only labor and takes the following linear functional form: \( l = f + q/\varphi \).

All firms pay the same fixed cost \( f \), but have different productivity levels \( \varphi > 0 \).\(^3\) Given the demand for individual varieties, each firm maximizes its profits by choosing the price of its own variety, which can be expressed as a mark-up over marginal cost: \( p(\varphi) = \frac{1}{\rho \varphi} \), where the wage rate is normalized to one. This, in combination with the definition of expenditure from (2.1), allows us to express firm revenues as:

\[
r(\varphi) = R(P\rho\varphi)^{\sigma-1},
\]

(2.2)

which implies that the ratio of any two firms’ revenues will only depend on their productivities:

\[
\frac{r(\varphi_i)}{r(\varphi_j)} = \left( \frac{\varphi_i}{\varphi_j} \right)^{\sigma-1}
\]

(2.3)

Furthermore, firm profits and labor demand can also be expressed as functions of productivity:

\[
\pi(\varphi) = \frac{r(\varphi)}{\sigma} - f \quad (2.4)
\]

\[
l(\varphi) = f + \frac{\sigma-1}{\sigma} r(\varphi).
\]

(2.5)

\(^3\)Thus, each variety \( \omega \) can be uniquely mapped to a single productivity level \( \varphi \).
Entry. There is a large pool of potential entrants into any industry, and prior to entry all the
firms are identical. To be able to produce, firms must pay a fixed entry cost $f_e > 0$, which is
sunk. After entry, firms draw their productivity $\varphi$ from a distribution $g(\varphi)$ with a cumulative
distribution $G(\varphi)$. If a firm has a low productivity draw upon entry, it may decide to exit
immediately and not produce. Firms that decide to produce face an exogenous probability of
death $\delta$ in each period. Since the productivity level of a firm does not change throughout its
lifetime, its optimal per-period profit level remains constant. A firm that enters the market
with productivity level $\varphi$ would then immediately exit if its per-period profits were negative.
This scenario implies a zero profit productivity cutoff condition $\pi(\varphi^a) = 0 \iff r(\varphi^a) = \sigma f$,
which determines the lowest productivity draw, $\varphi^a$, needed for a firm to stay in the market:
Any firm with productivity level $\varphi < \varphi^a$ will immediately exit. The productivity distribution
of the firms that stay in the market will thus be $\mu(\varphi) = \frac{g(\varphi)}{1-G(\varphi^a)}$, where $1-G(\varphi^a)$ is the
ex-ante probability of successful entry. This defines the aggregate productivity level $\bar{\varphi}$ as a
function of the cut-off level $\varphi^a$:

$$\bar{\varphi}(\varphi^a) = \left[ \frac{1}{1-G(\varphi^a)} \int_{\varphi^a}^{\infty} \varphi^{\sigma-1} g(\varphi) d\varphi \right]^\frac{1}{\sigma-1} \quad (2.6)$$

As shown in Melitz (2003), $\bar{\varphi}$ is also the average productivity level for the firms that choose
to produce and stay in the market. The combination of equations (2.4), (2.5), and the
zero profit productivity cutoff condition makes it possible to express average revenues as a
function of $\varphi^a$:

$$r(\bar{\varphi}) = \left[ \frac{\bar{\varphi}(\varphi^a)}{\varphi^a} \right]^\sigma f. \quad (2.7)$$

Free entry implies that new firms will enter the market as long as the average profit in the
industry is positive. Let $M$ denote the equilibrium number of firms, which ensures that
economic profits are competed away.\footnote{See Melitz (2003) for the properties of the equilibrium and details on aggregation.} In equilibrium, aggregate variables such as the CES
price index $P$ and aggregate expenditure $R$ can be expressed in terms of the equilibrium
number of firms and the average productivity:

\[ P = M^{\frac{1}{\tau}} p(\tilde{\varphi}) = M^{\frac{1}{\rho\tilde{\varphi}}} \]

\[ R = Mr(\tilde{\varphi}) \]

Equations (2.7), (2.8), and (2.9) allow us to express firm revenues in autarky, previously defined by equation (2.2), as a function of the zero profit productivity cutoff:

\[ r(\varphi) = \sigma f \varphi^{\sigma-1} \left( \frac{1}{\varphi^a} \right)^{\sigma-1} \]

which, in combination with equation (2.5), implies that the equilibrium number of workers employed by firm with productivity \( \varphi \) in autarky will be:

\[ l_a = f + (\sigma - 1) f^{\sigma-1} \left( \frac{1}{\varphi^a} \right)^{\sigma-1}. \]

Equation (2.11) implies that firms with higher productivity will employ more workers. The intuition behind this result is that the more productive firms will enjoy larger market shares and, therefore, will need and employ more workers.

### 2.2 Equilibrium under Trade and Protectionism

In this section, we derive the equilibrium number of workers employed in each domestic firm after the domestic economy is opened to trade. The world consists of \( n + 1 \geq 2 \) identical countries.\(^5\) Domestic firms can export their products to any country only after they pay a fixed export cost, \( f_x > 0 \), in addition to the fixed cost, \( f \), which they must incur to produce domestically. The decision to export is made after each firm draws its productivity level. Regardless of their export status, all domestic firms still incur the same overhead production cost. In addition, exporting firms face higher marginal cost of their exports due to

\(^5\)This implies that each country has \( n \geq 1 \) potential trading partners, and all countries share the same wages and same aggregate variables. In the empirical analysis we relax the assumption that the wages are identical.
to ad-valorem tariffs, which are assumed to be symmetric across all trading partners. Thus, each firm’s domestic pricing rule is given as before: \( p_d(\varphi) = \frac{1}{\rho \varphi} \), while the export price is: \( p_x(\varphi) = (1 + t)p_d(\varphi) = (1 + t)/\rho \varphi \), where subscript \( d \) stands for ‘domestic,’ and subscript \( x \) stands for ‘export.’ This price rule separability, combined with the assumption that each firm that exports must also engage in domestic production, implies separability of exporting firms’ revenues:

\[
 r(\varphi) = \begin{cases} 
 r_d(\varphi) & \text{if the firm does not export} \\
 r_d(\varphi) + nr_x(\varphi) = [1 + (n(1 + t))^{1-\sigma}] r_d(\varphi) & \text{if the firm exports to all countries.}
\end{cases}
\] (2.12)

In addition, this allows us to decompose each exporting firm’s profits into their domestic and foreign portions, \( \pi(\varphi) = \pi_d(\varphi) + n\pi_x(\varphi) \), where:

\[
 \pi_d(\varphi) = \frac{r_d(\varphi)}{\sigma} - f, \quad \pi_x(\varphi) = \frac{r_x(\varphi)}{\sigma} - f_x.
\] (2.13)

Each exporting firm’s labor demand can also be decomposed into its domestic and exporting portions, \( l^{ct}(\varphi) = l_{d}^{ct}(\varphi) + nl_{x}^{ct}(\varphi) \), where superscript \( ct \) denotes ‘costly trade’ and:

\[
 l_{d}^{ct} = f + r_d(\varphi)\frac{\sigma - 1}{\sigma}, \quad l_{x}^{ct} = f_x + r_x(\varphi)\frac{\sigma - 1}{\sigma}.
\] (2.14)

As in the autarky equilibrium, there is a large pool of potential entrants and each firm that enters the market with a productivity level \( \varphi \) would exit immediately if its domestic profits were negative. In addition, however, some firms will also choose to export as long as their productivity draw allows them to realize non-negative profits from exports. This scenario implies two zero-profit productivity cutoff conditions: one for domestic profits, \( \pi_d(\varphi^{ct}) = 0 \), which determines the lowest productivity draw, \( \varphi^{ct} \), needed for a firm to stay in business; and one for export profits, \( \pi_x(\varphi^{ct}_x) = 0 \), which determines the lowest productivity draw, \( \varphi^{ct}_x \), needed for a firm to export.

The fact that each firm must incur additional fixed costs, \( f_x \), in order to export implies that the lowest productivity draw, \( \varphi^{ct}_x \), needed for profitable exports is necessarily higher.
than the lowest productivity threshold, $\varphi^{ct}$, needed for domestic production. It is also important to establish the relationship between the zero-profit productivity cutoff in autarky and the two zero-profit productivity cutoffs in the trade equilibrium. As shown in Figure 1, the lowest productivity draw needed for domestic production must be higher once the country opens up to trade.

\[
\varphi^a \quad \varphi^{ct} \quad \varphi^{xt} \quad \varphi
\]

Figure 1: Firm Productivity and Costly Trade

This result is driven by the fact that some domestic firms find it profitable to start exporting, which leads to an increase in their demand for resources. This forces some of the least productive domestic firms out of the market and results in an increase in the average productivity level at home, as well as to an increase in the zero-profit productivity cutoff for domestic production.

Similar to the closed economy case, but this time using the average domestic productivity level $\bar{\varphi}$ and the average export productivity level $\bar{\varphi}_x$, we first express average revenues and all aggregates in terms of the zero-profit productivity cutoffs, and then use them to solve for the equilibrium number of workers employed in each firm depending on its export status. The labor equation for the firms that only serve the domestic market is very similar to the one describing the autarky equilibrium, the only difference being the zero domestic profit productivity threshold, $\varphi^{ct}$, which is higher in the trade equilibrium:

\[
l^{ct} = f + (\sigma - 1)f \varphi^{\sigma - 1} \left( \frac{1}{\varphi^{ct}} \right)^{\sigma - 1}.
\] (2.15)

Average export productivity is similar to its domestic counterpart, and is equal to $\bar{\varphi}(\varphi^{xt}) = \left[ \frac{1}{1 - \sigma(\varphi^{xt})} \int_{\varphi^{xt}}^{\infty} \varphi^{\sigma - 1} g(\varphi) d\varphi \right]^{\frac{1}{\sigma - 1}}$. 

\^6
The equilibrium number of workers employed by an exporting firm is:

\[ t^x = f + nf_x + (\sigma - 1)f \varphi^{\sigma-1} \left( \frac{1}{\varphi_{ct}} \right)^{\sigma-1} [1 + n(1 + t)]^{1-\sigma}. \] (2.16)

The intuition for the effects of introducing trade on the equilibrium firm-level employment described in equations (2.15) and (2.16) is clear. Once a country opens up to trade, the firms that export gain market share due to the fact that they are now producing for other countries as well. The increase in market share for the exporting firms is associated with more hires and an increase in employment. On the other hand, some of the firms that produce only for the domestic economy are forced out of the market while others incur losses associated with layoffs. Given that the change in market share depends on the firm’s export status, and hence on the productivity level of the firm, the number of laid-off workers and the number of new hires will be contingent on firm productivity as well.

Taking the difference between the equilibrium number of workers employed in a domestically producing firm in the trade equilibrium, defined in equation (2.15), and the equilibrium number of workers employed by the same firm in autarky, defined by equation (2.11), gives an expression for the firm-level layoffs caused by trade. Similarly, the difference between the equilibrium number of workers employed by an exporting firm, defined in equation (2.16), and the equilibrium number of workers employed by the same firm in autarky, defined by equation (2.11), defines the number of hires due to trade.\(^7\)

Ideally, one would like to be able to estimate both of the above relationships describing firm-level job destruction and firm-level job creation caused by trade. Empirically this is not possible for two reasons. First, in reality, we very rarely observe regime switching from autarky to trade. What we observe most of the time is trade liberalization. Therefore, in the next section, we derive and discuss the effects of trade liberalization on the labor market.

\(^7\)Technically, the exporting firms should also lay off some workers who are employed in production for the domestic market. As shown in Bernard \textit{et al.} (2007), however, the net effect on employment in the exporting firms will be job creation, while the net effect on employment in the firms that produce only domestically will be job destruction.
which we then quantify in our empirical analysis. Second, data availability allows us to measure only firm-level layoffs caused by trade as opposed to both trade-induced layoffs and trade-induced hires. To address this issue, we resort to the properties of our theoretical setting: We employ the two zero-profit cutoff conditions to express the zero-profit domestic productivity cutoff $\phi^{ct}$ in terms of the export productivity cutoff $\phi^{cx}$ and tariffs:

$$\phi^{ct} = \frac{\phi^{cx}}{(1 + t^{ct})} \left( \frac{f}{f_x} \right)^{\frac{1}{\sigma - 1}}. \hspace{1cm} (2.17)$$

which allows us to derive a structural equation for the number of workers employed in a domestically producing firm as a function of the zero profit export productivity cutoff and ad-valorem tariffs:

$$l^{ct} = f + (\sigma - 1) f_x \phi^{cx} \left( \frac{1 + t^{ct}}{\phi^{cx}} \right)^{\sigma - 1}. \hspace{1cm} (2.18)$$

As will become clear in the next section, equation (2.18) allows us to quantify the relationship between trade liberalization, firm productivity, and trade-induced layoffs by concentrating on the change in firm-level employment in domestically producing firms.

### 2.3 Trade Liberalization

In this section, we examine the impact of trade liberalization, in the form of a discrete tariff reduction from $t^{ct}$ to $t^{tl}$, on productivity and employment levels for domestic firms.$^9$ Qualitatively, the effects of trade liberalization are identical to the effects of opening up the economy to trade, as described in the previous section. Figure 2 depicts the changes in the zero-profit productivity cutoffs (both domestic and export) in response to trade liberalization.

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$^8$For simplicity and clarity of exposition, we only consider layoffs in domestically producing firms. As noted earlier however, equation (2.18) also describes employment of workers who are engaged in production for the domestic market in exporting firms. Empirically, this is not a problem since we observe trade-induced layoffs in all firms, regardless of their export status.

$^9$It should be noted that trade liberalization is symmetric, so that any decrease in domestic protection is matched by an equivalent decrease in foreign protection, with symmetric effects on foreign firms.
The export productivity cutoff decreases from $\phi^c$ to $\phi^d$ because, due to lower export costs, firms with lower productivity levels now find it profitable to export, which lowers the minimum productivity threshold required for exporting. Similarly, more foreign firms enter the home market, which forces some of the least productive firms to exit and leads to an increase in the minimum threshold needed for domestic production from $\phi^c$ to $\phi^d$.

As discussed earlier, the nature of available data forces us to concentrate on the labor demand for the firms that produce only domestically. In the previous section, we derived a structural equation (equation (2.16)) for the equilibrium number of workers employed by a domestically producing firm as a function of tariffs. It is possible to show that the equilibrium level of employment for domestic firms after trade liberalization is:

$$l^d = f + (\sigma - 1) f_x \phi^{-1} \left( \frac{1 + t^d}{\phi^d_x} \right)^{\sigma - 1}.$$

The difference between the number of workers employed by each domestically producing firm before trade liberalization (equation 2.18) and the number of workers employed by the same firm after trade liberalization (equation 2.19) defines the number of firm-level layoffs caused by trade liberalization:

$$l^c - l^d = (\sigma - 1) f_x \phi^{-1} \left( \frac{1 + t^c}{\phi^c_x} \right)^{\sigma - 1} - (\sigma - 1) f_x \phi^{-1} \left( \frac{1 + t^d}{\phi^d_x} \right)^{\sigma - 1}.$$

The assumption of trade liberalization, captured by a decrease in tariffs ($t^c$ to $t^d$) together with a decrease in the export productivity cutoff ($\phi^c$ to $\phi^d$), implies that the overall sign of the expression on right-hand side of equation (2.20) is strictly positive.

We finish this section by further formalizing the relationship between the zero domestic
productivity cutoff and the export productivity cutoff in the following proposition:

**Proposition 2.1** With symmetric trade liberalization, the increase in the zero-profit domestic productivity cutoff is smaller, in absolute value, than the decrease in the export productivity cutoff:

\[ \left| \frac{\varphi_{ct}^x - \varphi_{tl}^x}{\varphi_{ct}} \right| < \frac{\varphi_{ct}^{xt} - \varphi_{tl}^{xt}}{\varphi_{ct}^{xt}}. \]

The more a country liberalizes its trade policy, the bigger the difference between the changes in productivity cutoffs.

**Proof.** Apply the relationship in equation (2.17) to trade liberalization to show that:

\[ \left| \frac{\varphi_{ct} - \varphi_{tl}}{\varphi_{ct}} \right| = \frac{\varphi_{ct}^{xt} - \varphi_{tl}^{xt}}{\varphi_{ct}^{xt}}. \]  

Trade liberalization, measured by reduction in tariffs, implies \( \frac{1 + t_{ct}}{1 + t_{tl}} > 1 \), which means that \( \varphi_{x}^{tl} \frac{1 + t_{ct}}{1 + t_{tl}} > \varphi_{x}^{tl} \) and, therefore, \( \frac{\varphi_{ct}^{xt} - \varphi_{tl}^{xt}}{\varphi_{ct}^{xt}} = \left| \frac{\varphi_{ct} - \varphi_{tl}}{\varphi_{ct}} \right| < \frac{\varphi_{ct}^{xt} - \varphi_{tl}^{xt}}{\varphi_{ct}^{xt}}. \)

Intuitually, the lower magnitude in the increase in the zero-profit productivity cut-off can be explained by the secondary nature of the effect on the firms that produce only domestically. The direct effect of trade liberalization falls on the exporting side of the market where more firms can afford to bear the sunk cost of exporting and, therefore, the zero-profit export cut-off falls as a direct result of trade liberalization. The increase in the zero-profit cut-off for domestically producing firms is caused by the fact that resource prices are bid up by the exporters and that forces some of the less productive firms to leave the market.

### 3 Empirical Analysis

We start this section by describing the data employed in our estimations. Then, we consider series of alternative estimation specifications of equation (2.20). We start with a reduced-form model and finish with a full structural econometric specification. Our results indicate a negative and significant relationship between firm-level TFP and trade-induced layoffs and a positive effect of trade liberalization on the number of lost jobs due to trade. We also
provide empirical support for some key theoretical predictions from Melitz (2003) regarding the direction and the magnitude of the changes in the productivity cutoffs required for domestic production and exports. Sensitivity checks confirm the robustness of our findings.

3.1 Data Description

An advantage of our data is that it allows us to identify directly the trade-induced losses, in terms of layoffs, at the firm level. We use the Petition for Trade Adjustment Assistance Database (PTAA), a data set constructed and maintained by the Employment and Training Administration of the U.S. Department of Labor, to construct our trade-induced layoff variable. The PTAA data consists of firm-level data series at the 4-digit Standard Industrial Classification (SIC) level including the date when a petition for TAA was filed, when and whether the petition was certified, and the estimated number of workers to be laid off by each firm as a consequence of increase in the quantity of imports for the industry. We construct trade-induced layoff by first dropping all firms whose petitions were not certified for TAA, and then summing the total number of workers who were laid off due to trade, and therefore TAA certified, for each firm and year. After that, to calculate labor costs, we follow Keller and Yeaple (2007), and multiply the number of employees in each firm (data item 29 in Compustat) by the average industry wage, which is from the Annual Survey of Manufactures (ASM) for the corresponding year.

To calculate total factor firm productivity, the main explanatory variable in our estimations, we follow the procedure from Petrin and Levinsohn (2003) and the Stata routine -levpet- by Petrin et al. (2004). Petrin and Levinsohn (2003) emphasize the simultaneity problem and estimate production functions using intermediate inputs to control for unobservable productivity shocks. Once we calculate total factor productivity for each firm, we merge these data with the certified firms from the TAA data set, which determines the size of the estimation sample for our main analysis to be 2324 firm-level observations.\(^{10}\)

We also experiment with another TFP calculation routine -opreg- by Yasar et al. (2008) who adopt the methodology from Olley and Pakes (1996). This approach emphasizes the

\(^{10}\)The variables used for the calculation of TFP are in Appendix B.
simultaneity problem and selection bias for the calculation of productivity and allows for inter-industry TFP comparisons. Olley and Pakes (1996) uses investment as a proxy for unobservable productivity shocks.

In addition to firm-level data on layoffs and productivity, we also employ various labor and trade variables at the firm and at the industry level, including labor costs, imports, exports, tariffs, and elasticity of substitution. We use tariff data to test our theoretical predictions about trade liberalization. Even though non-tariff trade barriers (NTBs) are probably a more significant and relevant measure of protection, we use tariffs for two reasons. First, comprehensive data on NTBs for the period of investigation are not available. Second, we believe that U.S. tariffs, which, for the period of interest in this paper, are determined under the regulations and rules of the General Agreement on Tariffs and Trade (GATT) and the World Trade Organization (WTO), are the more appropriate measure of protection in the current theoretical setting, which assumes symmetric trade costs and symmetric trade liberalization. Therefore, we employ the change in tariffs to measure trade liberalization.\footnote{In order to keep our sample size as large as possible, we use tariffs at the 3-digit SIC level to obtain our main estimation results. In the sensitivity analysis, we also experiment with tariffs at the 4-digit SIC level and obtain very similar estimates.}

We use two sources for data on tariffs. Import-weighted average tariffs for the period 1980-1988 are from Bernard et al. (2006) and the tariffs for the years after 1989 are from the Trade Analysis Information System (TRAINS).\footnote{We accessed TRAINS through the World Bank’s World Integrated Trade Solution (WITS) software at http://wits.worldbank.org/witsweb/}.

Data on sectoral imports and exports classified according to the 4-digit SIC 1972-basis are also from two sources. Data on imports up to 1989 are from Feenstra (1996) and data on exports up to 1990 are from Feenstra (1997). Trade flows for the years after 1990 (1989 for imports) are from the United Nations Conference on Trade and Development (UNCTAD) and TRAINS. We calculate labor costs as the product of the number of employees in each firm (from Compustat) and the average industry wage (from the Annual Survey of Manufactures) for the corresponding year. Finally, data on the elasticity of substitution is...
from Broda and Weinstein (2006), who estimate and report 3-digit HS indexes for 73 countries. We aggregate the original elasticity numbers to the 3-digit SIC level of commodity aggregation by using the value of sectoral imports as weights.

3.2 Estimation Specifications and Analysis

Our first take on testing (2.20) is to estimate a reduced-form linearized version of the structural model, which relates the logarithm of trade-induced firm-level layoffs to the logarithm of the interaction between firm’s productivity and lagged industry tariffs and the logarithm of the interaction between firm productivity and current tariffs:

\[ \text{LAYOFF}_i = \alpha_0 + \alpha_1 \text{LAGT}_j \times \text{TFP}_i + \alpha_2 T_j \times \text{TFP}_i + \varepsilon_{ij}, \quad (3.1) \]

where \( \text{LAYOFF}_i = \ln(l^t_i - l^l_i) \) is the logarithm of the number of workers who are laid off from firm \( i \) due to import competition, \( \text{TFP}_i = \varphi_i \) is the total factor productivity of firm \( i \), \( T_j \) is the ad-valorem tariff faced by the international competitors of import-competing firm \( i \) operating in industry \( j \), and \( \text{LAGT}_j \) is the one-year lagged value of \( T_j \). As suggested by the structural model, we expect the coefficient in front of the first term, \( \alpha_1 \), to be negative, implying a direct relationship between the interaction of total factor productivity and lagged tariffs and the number of workers laid-off by each import-competing firm due to trade. The estimate of \( \alpha_2 \) should be negative, implying an inverse relationship between the interaction of current tariffs and productivity: all else equal, higher current tariffs are associated with fewer layoffs.

Results obtained by estimating (3.1) directly are reported in column 1 of Table 1. As can be seen from the table, the estimates of the coefficients on both terms are significant and have the expected signs. The interaction between lagged tariffs and productivity has positive effect on layoffs while the interaction of current tariffs and productivity has negative effect on layoffs. In column 2 of the table, we estimate equation (3.1) with a set of industry dummies to control industry-level characteristics that may affect trade-induced layoffs but are not explicitly included in the theoretical specification (such as comparative advantage,
<table>
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Standard errors in parentheses
+ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$
for example). Estimation results obtained with sector specific intercepts are qualitatively identical to the previous findings but are larger in magnitude. This suggests a downward bias in the estimates when the unobservable industry specific characteristics are not controlled for.

In order to receive TAA, US firms must go through a formal process of certification, where the government determines whether the firm is really affected by trade or it suffers for any other reason. One would expect that if two firms produce identical products and one of them has been TAA-certified, the other will also be eligible to enter the program. Surprisingly this is not always the case. There were cases in the data when even branches of the same company, producing identical products but operating in different states, have different outcomes when applied for TAA. This suggests that overall political affiliation of a given state might affect whether a layoff is labeled as trade induced or not. Furthermore, this might create a selection bias. We think that whether a state is “blue” or “red” should not be related to any firm’s performance and trade-induced layoff, in particular. Thus, we identified the political orientation of the state for each firm in our sample based on electoral results in year 2000 and used it as an exclusionary variable in the selection model. To construct the exclusionary variable, POLIT, we assign a value of one if a state is classified as republican.

The fact that we are investigating the effect of trade liberalization on labor layoffs only for the firms that are labeled as suffering from trade implies that our results are subject to a selection bias. The firms in the estimation sample might have been selected in a non-random manner. To address this problem, we follow Heckman (1979) and set up the following econometric model:

\[
\text{LAYOFF}_i = \alpha_0 + \alpha_1 \text{LAGT}_j \times TFP_i + \alpha_2 T_j \times TFP_i + \varepsilon_{1ij},
\]

(3.2)

where layoff is observed if:

\[
\gamma_0 + \gamma_1 \text{EXCL}_i + \gamma X_{ij} + \varepsilon_{2ij} > 0.
\]

(3.3)
Here, $\varepsilon_{1ij}$ and $\varepsilon_{2ij}$ are correlated and jointly normally distributed. Equation (3.3) is our selection equation based on whether a firm suffers from trade or not. $EXCL_i$ is the exclusionary variable, which we describe below, and $X_{ij}$ is a set of control variables, which we believe may affect the outcome of the TAA certification process. The control covariates that we use to estimate (3.3) include the level of trade protection (proxied by tariffs), firm-level labor costs, and elasticity of substitution.

We employ Maximum Likelihood Estimation (MLE) and the Heckman selection model (3.2)-(3.3) to obtain the estimates reported in the last column of Table 1. Our first step, however, is to check whether our exclusionary variable has any explanatory power in the structural equation (3.2). As can be seen from column 3, we find no significant relation between the political affiliation of a state and the number of workers laid off due to trade from a firm operating in this state. This is supported by the insignificant coefficient on POLIT. In addition, the signs, the significance, and the magnitude of the other explanatory variables do not change. Overall, these results suggest that POLIT might be a good exclusionary variable for our selection model.

Turning to the estimation results from the selection specification (3.2)-(3.3), presented in column 4, we see that the coefficient on POLIT in the first-stage equation is significant. This, in combination with a Wald test ($\chi^2_1 = 12.93$) reported at the bottom of column 4, validates our selection model. The negative sign of the coefficient on POLIT implies that, all else equal, it is less likely to become TAA-certified in a republican state. The negative sign of the coefficient estimate of TARIFF is expected. It suggests that higher level of tariffs are associated with lower probability to enter the TAA program. The intuition is clear; higher tariffs result in less imports and less loss market shares for the domestic firms, which will lay off fewer workers in return. Higher labor costs are associated with lower probability to suffer from trade-induced layoff and qualify for TAA. This is captured by the negative and significant coefficient on LABOR COST, and can be explained with the fact that the

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13This, by itself, is a very interesting finding, which we investigate more thoroughly in a separate paper. For the current purposes, our only goal is to find a reasonable (theoretically sound and satisfying the econometric tests) exclusionary variable, and POLIT meets our needs.
better paid workers might have more human capital and represent firms in industries in which the US has a comparative advantage. Finally, we find that firms that operate in industries with higher elasticity of import demand are less likely to become TAA-certified. Estimation results obtained after controlling for selection are very similar to the results presented in column 2. The estimate coefficient on the interaction between TFP and lagged tariffs is positive and significant, while the estimate of the coefficient on the interaction between TFP and current tariffs is negative and significant. These results suggest that the bias when selection is not controlled for is not severe.

While encouraging, in terms of their statistical significance, the findings from Table 1 are not very informative. Not only the reduced-form specification (3.1) precludes any structural interpretation of the estimates but it also does not allow for decomposition of the effects of productivity and trade liberalization on the level of trade-induced layoffs. The latter is our next goal and to achieve it we start by rewriting equation 2.20 as:

\[ l^{ct} - l^{tl} = (\sigma - 1) f_x \varphi^{\sigma - 1} \left[ \left( \frac{1 + t^{ct}}{\varphi^{ct}} \right)^{\sigma - 1} - \left( \frac{1 + t^{tl}}{\varphi^{tl}} \right)^{\sigma - 1} \right], \quad (3.4) \]

and translating it into the following reduced-form econometric model:

\[ LAYOFF_i = \beta_0 + \beta_1 TFP_i + \beta_2 LIB_j + \epsilon_{ij}. \quad (3.5) \]

Here, TFP is the total factor firm productivity and \( LIB_j \) is the difference between the one-year lagged and current ad-valorem tariffs in industry \( j \), which we use as a proxy for the magnitude of liberalization.

Results obtained by estimating (3.5) directly are reported in column 1 of Table 2. As can be seen from the table, the estimates of the coefficients on both terms are significant at any level. As expected, trade liberalization is directly related to layoffs. This is captured by the positive and significant estimate of \( \beta_2 \) which means that the more liberalized a sector is there will be more firm-level layoffs. The estimate of the coefficient on TFP is negative and also very significant. This suggests that more productive firms will lay off fewer workers. In the
Table 2: Reduced-form Estimation Results

<table>
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<td>(6.205)**</td>
<td>(1.211)</td>
<td>(1.637)**</td>
<td>(1.646)**</td>
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<td>(0.774)**</td>
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<td></td>
<td>(0.134)**</td>
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<td>$R^2$, $\chi^2$</td>
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<td>0.021</td>
<td>0.087</td>
<td>12.86</td>
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</table>

Standard errors in parentheses

$+ p < 0.10$, * $p < .05$, ** $p < .01$
light of the Melitz’s (2003) model, the intuition for this result is that the more productive
domestic firms loose less of their market shares as a consequence of trade liberalization
and, therefore, lay off fewer workers. Not only the negative and significant coefficient on
TFP implies a negative relationship between productivity and trade-induced layoffs, but it
could also be used to shed light on the changes in the productivity thresholds in Melitz’s
framework.

To show this more clearly, we set the elasticity substitution in equation 2.20 (or alterna-
tively in 3.4) to be equal to two and derive the following ‘semi-structural’ model:14

\[ t^{ct} - t^{tl} = f_x \left[ \frac{1}{\varphi_{ct}} - \frac{1}{\varphi_{tl}} \right] \varphi + f_x \frac{t^{ct} - t^{tl}}{\varphi_{ct}} \varphi (t^{ct} - t^{tl}) + f_x \left[ \frac{1}{\varphi_{ct}} - \frac{1}{\varphi_{tl}} \right] \varphi t^{tl}. \] (3.6)

Equation (3.6) allows us to estimate and provide structural interpretation of the relationship
between firm-level trade-induced layoffs, firm-level productivity, and trade liberalization
through the coefficients in front of \( \varphi \), \( \varphi (t^{ct} - t^{tl}) \) and \( \varphi t^{tl} \). Our expectations for the signs
of these coefficients are formed based on the theoretical predictions of the model. The
expression in brackets in front of the first term is negative, since the productivity cut-off
level for exporting increases with trade liberalization. This suggests that, all else equal, the
direct effect of productivity on trade-induced layoffs should be negative, and explains the
negative and significant estimate of the coefficient on TFP from the first column of Table
2. We expect the second coefficient to be positive. On the one hand, this implies that, for
a given level of productivity, higher levels of trade liberalization should be associated with
more layoffs. On the other hand, the structure of the second firm is such that, for a given
level of trade liberalization, an increase in firm productivity will result in more layoffs. This
effect works in the opposite direction of the direct effect of productivity on layoffs captured
by the first term in (2), and its magnitude will depend on the level of trade liberalization.

14 We experiment with alternative plausible values for the elasticity of substitution in Appendix A. Our
main empirical results do not change, and are available upon request. In addition, in the full structural
econometric analysis, presented below, we also allow for the elasticity of substitution to vary across industries,
which further reinforces our main findings.
Finally, the negative sign of the third term implies that, all else equal, firms operating in the more protected industries will suffer fewer trade-induced layoffs.

Equation (3.6) translates into the following econometric specification:

\[ LAYOFF_i = \alpha_0 + \alpha_1 TFP_i + \alpha_2 LIB_j \times TFP_i + \alpha_3 T_j \times TFP_i + \varepsilon_{ij}, \quad (3.7) \]

where all variables are defined above, however, the left-hand side variables are now in levels as required by semi-structural specification, and \( \alpha_1 = f_x \left[ \frac{1}{\varphi_T} - \frac{1}{\varphi_{TL}} \right] < 0, \) \( \alpha_2 = \frac{f_x}{\varphi_T} > 0, \) and \( \alpha_3 = f_x \left[ \frac{1}{\varphi_T} - \frac{1}{\varphi_{TL}} \right] < 0. \) Note that theory restricts the coefficients on the first and the third terms in equation (3.7) to be equal. We impose this restriction in our regression analysis. Results from the estimation of (3.7) are reported in column 2 of Table 2 and are as expected: The negative but insignificant coefficient on TFP indicates a weak inverse relationship between total firm productivity and trade-induced firm-level job destruction, which is in accordance with theory.\(^{15}\) We also establish a positive and significant relationship between the degree of trade liberalization interacted with TFP, and trade-induced layoffs. As expected, the positive coefficient on LIB×TFP implies that, all else equal, the more a country opens up to trade the more layoffs there will be in the import competing industries and firms. Finally, we find only weak support for the prediction that, all else equal, firms operating in more protected industries will layoff fewer workers. This is suggested by the negative but insignificant coefficient on T×TFP.

Estimation results reported in columns 3 and 4 of Table 2 are obtained after controlling for unobservable sector-specific fixed effects and accounting for selection, respectively. As compared to the findings in column 2, the results in column 3, obtained with industry fixed effects, show improvement since the estimates of the coefficients on TFP and T×TFP are now negative but also statistically significant at any level. Thus, we find support for the theoretical predictions that more productive firms lay off fewer workers, implied by the negative and significant coefficient on TFP, and that firms that operate in more protected industries suffer fewer layoffs.\(^{15}\) It should be emphasized that we cannot interpret the coefficient on TFP directly as the total effect of productivity on layoffs since TFP enters interactively also in the other two terms in our model. We decompose and analyze the TFP effect below.
industries will layoff fewer workers, suggested by the negative and significant coefficient on T×TFP. In terms of the estimates’ magnitude, we conclude that not controlling for sector specific characteristics biases the estimates of TFP and LIB×TFP down. Results from column 4 indicate that the consequences of not accounting selection are not severe. The estimates of the coefficients on all terms are significant and have the expected signs and not accounting for selection results in a slight downward bias in the estimates of the effects of TFP and LIB×TFP.

The estimates obtained with the semi-structural estimation (reported in Table 2) do not allow us to recover directly the structural parameters $\varphi_{ct}^e$ and $\varphi_{xt}^l$, which correspond to the productivity cutoffs for the exporting firms before and after trade liberalization. However, under the assumption that our theoretical model is a true representation of the data, we can draw some important inferences on the direction and the magnitude of the changes not only in the export productivity cutoffs, but also in the domestic productivity cutoffs. The negative and significant coefficient estimates on TFP and LIB×TFP, imply that the export productivity cutoff before trade liberalization is higher than the corresponding cutoff after trade liberalization, which is exactly what theory predicts. To see this, consider either the theoretical expression of the TFP coefficient or of the LIB×TFP coefficient $\alpha_1 = \alpha_3 = f_x \left[ \frac{1}{\varphi_{e}^x} - \frac{1}{\varphi_{l}^x} \right]$. Our estimate of $\alpha_1$ is significantly lower than zero, which implies that $\varphi_{ct}^e$ is greater than $\varphi_{xt}^l$. Using the relation between domestic productivity cutoffs, tariffs, and export productivity cutoffs, described in equation (2.21), we show that the zero-profit productivity cutoff before trade liberalization is lower than the zero-profit productivity cutoff after trade liberalization.

Employing the coefficients on TFP and LIB×TFP from equation (3.1), we calculate and compare the percentage changes in the export and the domestic zero-profit productivity cutoffs. First, we express the decrease in export productivity cutoff, in terms of our estimated coefficients, as:

$$\frac{\varphi_{ct}^e - \varphi_{xt}^l}{\varphi_{ct}^e} = \frac{\alpha_1}{\alpha_1 - \alpha_2}. \quad (3.8)$$

Applying the Delta Method, we find the above relationship to be significant, and we es-
timate that trade liberalization results in a 12.9% (standard error 0.042) decrease in the export productivity threshold. In order to estimate the increase in the domestic zero-profit productivity cut-off, we employ equation (3.8) in combination with equation (2.21), and we use the average tariffs before and after trade liberalization. We find the increase in the domestic zero-profit productivity cut-off to be significant and equal to 12.7% (standard error 0.055). The 0.2% difference between the changes in the export productivity and domestic productivity cut-offs is not significantly different from zero at any significance level, and is not in accordance with the theoretical prediction of Proposition 1, which states that the increase in the zero-profit domestic productivity cutoff should be smaller, in absolute value, than the decrease in the export productivity cutoff. One possible explanation for the failure of our results to satisfy Proposition 1 is that we depart from a full structural estimation by restricting the elasticity of substitution to be equal to two. We relax this assumption below.

We are also able to quantify the effect of trade liberalization on trade-induced, firm-level layoffs. Since our trade liberalization variable enters the estimation equation in levels, while the layoffs are measured in logs, to calculate the elasticity of trade-induced layoffs with respect to trade liberalization, we multiply the coefficient in front of the interaction term LIB×TFP by the means of the TFP and LIB variables.\textsuperscript{16} We find that a one percent increase in trade liberalization results in a significant increase of 5.7% (standard error 0.012) in firm-level layoffs caused by trade.

In our final attempt to quantify the relationship between trade-induced firm-level layoffs, firm heterogeneity, and trade liberalization, we take literally the predictions of the theoretical model and we perform a full structural estimation of equation (2.20):

\[
\ell_{it} - \ell_{tl} = \left( \sigma_j - 1 \right) f_x \varphi_i^{\sigma_j - 1} \left( \frac{1 + t_{jt}}{\varphi_{xt}} \right)^{\sigma_j - 1} - \left( \sigma_j - 1 \right) f_x \varphi_i^{\sigma_j - 1} \left( \frac{1 + t_{tl}}{\varphi_{xt}} \right)^{\sigma_j - 1}. \tag{3.9}
\]

Here, \( \ell_{it} - \ell_{tl} \) is trade-induced labor layoff in levels; \( \sigma_j \) is industry specific elasticity of substitution at the 3-digit SIC level of aggregation; \( \varphi_i \) is total factor firm productivity; and

\textsuperscript{16}In general, in a log-linear model, the regression equation is \( \ln Y = a + bX + \varepsilon \), and the slope coefficient is \( \frac{d\ln Y}{dX} = (dY/dX)/Y \). In order to calculate the elasticity, the coefficient is multiplied by \( X \).
and $t^*_j$ and $t^d_j$ are lagged and current ad-valorem tariffs at the the 3-digit SIC level, respectively. We employ a nonlinear least-squares estimation with robust standard errors to obtain the values of the parameters of interest from (3.9): $f_x$, which is the fixed export cost; $\varphi^*_x$, which is the lowest productivity draw needed for a firm to export before trade liberalization; and $\varphi^d_x$, which is the lowest productivity draw needed for a firm to export after trade liberalization.

Structural estimation results are reported in Table 3. In column 1, we estimate (3.9) directly as it is. In column 2, we control for any sector-specific unobserved characteristics, which may affect trade-induced layoffs but are omitted in the model, by adding industry fixed effects. In addition to the sector dummies, in column 3 we account for selection and estimate the model following Heckman (1979). The three sets of estimation results are similar, and several properties stand out. First, all estimates are significant at any level and have the expected signs. Second, export fixed costs are large. Third, as suggested by theory, the export productivity cutoff falls as a result of trade liberalization. The difference between $\varphi^*_x$ and $\varphi^d_x$ is statistically and economically significant. Based on the estimation results which control for both industry fixed effects and selection (reported in column 3 of the table), we estimate the fall in the export productivity cutoff to be 5.9% and the

| Table 3: Structural Estimation Results |
|-----------------|-----------------|-----------------|
|                 | (1) | (2) | (3) |
| $f_x$ BASE      | 2247 | 1776 | 1637 |
| (704)**         | (610)** | (554)** |
| $\varphi^*_x$  | 1.855 | 1.605 | 1.591 |
| (0.077)**       | (0.058)** | (0.043)** |
| $\varphi^d_x$  | 1.742 | 1.530 | 1.497 |
| (0.083)**       | (0.061)** | (0.049)** |
| FEs Yes         | Yes | Yes |
| $\lambda$      | 339.94 | (151.79)** |
| $N$             | 1331 | 1331 | 2288 |
| $R^2, \chi^2$  | 0.024 | 0.058 | 269.7 |
| $\partial (c^*_i - c^d_i)/\partial \varphi$ | -1039.131 | -1191.87 | -1523.9 |
| (409.74)*       | (524.04)* | (643.63)* |

Standard errors in parentheses
+ $p < 0.10$, * $p < .05$, ** $p < .01$
increase in the domestic productivity cutoff to be 5.7%. Finally, our estimates indicate that not accounting for industry-specific characteristics and selection biases the estimates of the export fixed costs and the export productivity cutoffs up.

Next, we quantify the net effect of productivity on trade-induced layoffs. To do so, we use average tariffs, average lagged tariffs, and average elasticity of substitution to estimate:

$$\frac{\partial (t_i^a - t_i^l)}{\partial \phi} = (\bar{\sigma} - 1)^2 f_x \phi^{\bar{\sigma} - 2} \left[ \left( \frac{1 + \bar{\sigma} t_i^x}{\phi x} \right)^{\bar{\sigma} - 1} - \left( \frac{1 + \bar{\sigma} t_i^l}{\phi x} \right)^{\bar{\sigma} - 1} \right]. \quad (3.10)$$

Employing the coefficient estimates from column 3 of Table 3, which we believe are the most correctly specified, we calculate the effect of productivity on trade-induced layoffs to be negative, significant, and equal to -1523.9 (standard error 643.63). This means that, all else equal, a one percent increase in the level of total factor firm productivity above the average for the industry will save about 1524 jobs that will otherwise be lost because of trade liberalization. As can be seen from Table 3, other specifications give similar results for the negative relations between TFP and trade-induced layoffs. Our estimates of these effects, presented at the bottom of the table, range between 1039 and 1192 workers. This suggests that not controlling for selection leads to a downward bias in the effect of productivity on trade induced firm-level layoffs. We also estimate the effects of productivity by industry. To do this, we employ the average tariffs, average lagged tariffs, and average elasticity of substitution at the 2-digit SIC level of aggregation to estimate (3.10). Results are reported in Table 4. As can be seen from the table, the relationship between TFP and trade layoffs is always negative and statistically significant at least at the 5% level. The magnitude of the relationship varies widely by industry. An increase in productivity will save least jobs in industries such as Apparel, Furniture, and Petroleum and Coal, and will have strong effect in sectors including Primary and Fabricated Metals and Transportation Equipment.

We finish our empirical analysis by performing series of sensitivity and robustness checks.\(^{17}\) Our theoretical setting assumes that wages are equal across different firms. However, that is not the case in reality. Therefore, we control for different wages by including firm-level

\(^{17}\)Estimation results from these experiments are available upon request.
Table 4: Productivity and Layoffs

<table>
<thead>
<tr>
<th></th>
<th>(1) SIC</th>
<th>(2) Layoffs</th>
<th>(3) Std.Err.</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>-1519.2</td>
<td>660.0</td>
<td></td>
</tr>
<tr>
<td>22</td>
<td>-1649.9</td>
<td>724.1</td>
<td></td>
</tr>
<tr>
<td>23</td>
<td>-335.4</td>
<td>129.0</td>
<td></td>
</tr>
<tr>
<td>24</td>
<td>-1092.5</td>
<td>437.9</td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>-345.7</td>
<td>130.0</td>
<td></td>
</tr>
<tr>
<td>26</td>
<td>-1573.8</td>
<td>777.3</td>
<td></td>
</tr>
<tr>
<td>27</td>
<td>-885.6</td>
<td>372.1</td>
<td></td>
</tr>
<tr>
<td>28</td>
<td>-1352.0</td>
<td>565.6</td>
<td></td>
</tr>
<tr>
<td>29</td>
<td>-120.5</td>
<td>43.6</td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>-997.7</td>
<td>399.7</td>
<td></td>
</tr>
<tr>
<td>31</td>
<td>-1502.7</td>
<td>603.6</td>
<td></td>
</tr>
<tr>
<td>32</td>
<td>-1165.6</td>
<td>483.7</td>
<td></td>
</tr>
<tr>
<td>33</td>
<td>-1944.0</td>
<td>885.8</td>
<td></td>
</tr>
<tr>
<td>34</td>
<td>-1783.3</td>
<td>787.9</td>
<td></td>
</tr>
<tr>
<td>35</td>
<td>-1370.0</td>
<td>577.6</td>
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</tr>
<tr>
<td>36</td>
<td>-990.4</td>
<td>396.9</td>
<td></td>
</tr>
<tr>
<td>37</td>
<td>-1796.3</td>
<td>874.2</td>
<td></td>
</tr>
<tr>
<td>38</td>
<td>-1244.0</td>
<td>510.3</td>
<td></td>
</tr>
<tr>
<td>39</td>
<td>-893.1</td>
<td>362.1</td>
<td></td>
</tr>
</tbody>
</table>

labor costs as a regressor in our empirical specifications. We find that labor costs have a positive and significant effect on firm layoffs, which can be explained with downward-sloping labor demand: The more costly labor is, the more workers are laid off.

Additional control variables, which we believe are important determinants of the magnitude of firm-level job destruction when a country liberalizes its trade policy, include imports and exports and the elasticity of substitution. The intuition for controlling for imports is clear: The more an industry is exposed to foreign competition, the more workers in this industry are likely to lose their jobs due to trade. We include exports because we expect that, all else equal, fewer jobs will be lost in industries with larger exports. Theory suggests that the elasticity of substitution across sectors should be controlled for, even in reduced-form estimations. We find a positive and significant relationship between imports and trade-induced layoffs and a negative and significant relationship between exports and trade layoffs. Our results indicate a positive relationship between the elasticity of substitution and the number of jobs lost to trade. This implies that, all else equal, firms operating in sectors with higher
elasticity of substitution will suffer more layoffs.

Finally, we turn to trade liberalization and tariffs. To obtain our main estimation results, we employ tariffs at the 3-digit SIC level. We also experiment with tariffs at the 4-digit SIC level. Arguably, 4-digit SIC tariffs are a better measure of protection for our purposes since we want to work with data at a disaggregation level which is as close as possible to the firm-level. The new estimation results are very similar to our previous findings.

4 Conclusion

In this paper, we attempted to fill a gap between the vast amount of theoretical literature devoted to studying the interactions between firm productivity, trade, and trade liberalization, and the lack of empirical evidence for these relationships when labor markets are in question. The main contribution of our work is twofold: First, concentrating on the labor market we use reliable data, that enables us to measure directly firm-level layoff caused by trade, and employ a selection model to quantify the relationships between productivity, trade liberalization, and trade-induced layoffs. More specifically, we find that a one-percent increase in firm’s total factor firm productivity above the average for a sector saves between 120 and 1990 jobs, depending on the industry, that would be lost due to trade liberalization, while, on average, an additional one-percent of trade liberalization increases the number firm-level, trade-induced layoffs by 6%. Second, we provide empirical evidence for key theoretical predictions from previous studies regarding the direction and magnitude of the changes in the minimum productivity thresholds required for domestic production as well as exports. In particular, our results suggest that the zero-profit productivity cutoff for domestic firms will increase while the export productivity cutoff will fall as consequences of trade liberalization. In addition, we find that, in absolute terms, the change in the zero-profit productivity cutoff for domestic production will be smaller than the change in the export productivity cutoff.

An interesting extension of this paper will be to test whether and how our findings differ for industries with comparative advantage as opposed to industries with comparative disadvantage. Bernard et al. (2007), extend Melitz’s (2003) model by allowing for firm
heterogeneity in a comparative advantage setting. They show that the zero-profit productivity cutoff increases in both types of industries but the increase is bigger in the sectors with comparative advantage. In addition, the export productivity cutoff is closer to the zero productivity cutoff in sectors with comparative advantage. In regard to the labor market, their findings suggest that trade liberalization results in simultaneous job creation and job destruction in all industries, but the comparative disadvantage industries exhibit net job destruction while comparative advantage industries experience net job creation. After identifying the sectors with and without comparative advantage, our data will allow for direct testing of whether the effects of trade liberalization on the productivity cutoffs are industry-type contingent.
References


Appendix A: Alternative Specification of $\sigma$

To obtain our main estimation results, we work with the simplest form of our structural labor equation by setting the elasticity of substitution to be equal to two. Here, we formally expand the polynomial defined in equation (2.18). Starting with the original equation (2.18),

$$l_i^t - l_i^t = (\sigma - 1) f_x \varphi_i^{\sigma-1} \left[ \left( \frac{1 + t^t}{\varphi^t_x} \right)^{\sigma-1} - \left( \frac{1 + t^t}{\varphi^t_x} \right)^{\sigma-1} \right], \quad (4.1)$$

we can show that for reasonable values of $\sigma$, it takes the following forms:

$$l_i^t - l_i^t = 
\begin{cases} 
  f_x \left[ \frac{1}{\varphi^2_x} - \frac{1}{\varphi^t_x} \right] \varphi_i^2 + \frac{f_x}{\varphi^t_x} \varphi_i t^t - \frac{f_x}{\varphi^t_x} \varphi_i t^t, & \sigma = 2 \\
  f_x \left[ \frac{1}{(\varphi^2_x)^2} - \frac{1}{(\varphi^t_x)^2} \right] \varphi_i^2 + \frac{f_x}{(\varphi^t_x)^2} \varphi_i^2 t^t + \frac{f_x}{(\varphi^t_x)^2} \varphi_i^2 (t^t)^2 \\
  - \frac{f_x}{(\varphi^t_x)^2} \varphi_i^2 t^t - \frac{f_x}{(\varphi^t_x)^2} \varphi_i^2 (t^t)^2, & \sigma = 3 \\
  f_x \left[ \frac{1}{(\varphi^3_x)^3} - \frac{1}{(\varphi^t_x)^3} \right] \varphi_i^3 + \frac{f_x}{(\varphi^t_x)^3} \varphi_i^3 t^t + \frac{f_x}{(\varphi^t_x)^3} \varphi_i^3 (t^t)^2 + \frac{f_x}{(\varphi^t_x)^3} \varphi_i^3 (t^t)^3 \\
  - \frac{f_x}{(\varphi^t_x)^3} \varphi_i^3 t^t - \frac{f_x}{(\varphi^t_x)^3} \varphi_i^3 (t^t)^2 - \frac{f_x}{(\varphi^t_x)^3} \varphi_i^3 (t^t)^3, & \sigma = 4 \\
  \ldots & \sigma \in \{5, 6, 7\} 
\end{cases}$$

We estimate the above equations, derived for different values of $\sigma$, to find that the new estimates, available upon request, are very similar to the main results reported in Table ?? and the sensitivity analysis presented in Table ??.

Appendix B: Variables for TFP Calculations

- **Compustat - Firm Level Variables**
  - Output: Net Sales
  - Material Cost: Total Cost of Goods Sold + Selling, General, and Administrative Expenses - Capital Depreciation and Amortization - Labor Cost
– Labor: Total Number of Employees
– Capital: Value of Property, Plant and Equipment Net of Depreciation
– Investment: Capital Expenditures

• Bartelsman, Becker, and Gray (2001) - Industry Level Variables
  – Production Workers
  – Production Worker Wages
  – Deflator for value of shipments
  – Deflator for material costs
  – Deflator for Investment