Trade Liberalization, Firm Heterogeneity, and Labor Layoffs: An Empirical Investigation

by

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Abstract

This is the first empirical attempt to provide evidence for the interaction between firm-level total factor productivity and trade liberalization as key determinants of firm-level job destruction caused by trade. Employing an original US firm-level data, we test and find support for theoretical predictions from Melitz (2003), whose model we use to derive an explicit equation relating firm productivity and trade-induced layoffs when a country liberalizes its trade policy. In addition, we incorporate intuitive labor market interactions that are not explicitly captured in Melitz's model. These allow us to reconcile some discrepancies between theory and empirical work.

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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.[1] 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 the zero-profit productivity cutoff and a decrease in the export productivity cutoff, defined as the minimum productivity level needed for a firm to enjoy profitable exports.

In this paper, we test (and provide empirical support for) some important predictions from the structural Melitz model regarding the direction and the magnitude of the changes in the zero-profit productivity cutoff and in the export productivity cutoff when a country liberalizes its trade policy. In addition, our main contribution is that we are able to quantify the relationship between firm productivity, trade liberalization and firm-level layoffs caused by trade liberalization. To do this, we stay close to the original Melitz framework but, naturally, we concentrate on labor market outcomes, and we employ a reliable and original data set that allows us to directly identify *firm-level, trade-induced* layoffs.[2] Finally, by allowing for some intuitive labor market interactions that are not explicitly captured in the Meliz model, we reconcile some discrepancies between theory and empirics and we open avenues for further theoretical work that will bring the firm-heterogeneity literature closer to the data.

We start our theoretical exposition by deriving firm-level employment in an autarky equilibrium. Then, we determine the equilibrium number of workers for each firm when

[1]See Bernard, Redding, and Schott (2007), Egger and Kreickemeier (2007), Helpman, Melitz, and Yeaple (2004) among many others.

[2]This database is the Petition for Trade Adjustment Assistance (PTAA), which constructed and maintained by the Employment and Training Administration of the U.S. Department of Labor.

the country opens to costly trade and exercises protection. Finally, we describe the case of trade liberalization, which is the basis for our empirical analysis. The theoretical predictions of our structural model in regard to the labor market outcomes suggest that, all else equal, symmetric trade liberalization with the rest of the world will result in: (a) layoffs for the firms that do not export; (b) gross layoffs in the domestic segment of the exporters; (c) gross hires in the export segment of the exporters; and, (d) net hires for the exporting firms. In addition, we show that all of the above effects are stronger for the more productive firms and for more pronounced trade liberalization.

Since our data allows us to identify only trade-induced layoffs (as opposed both layoffs and hires), in our empirical analysis we are able to test only some of the model's theoretical predictions. Overall, our results indicate that firm productivity, trade liberalization, and the interactions between them are indeed key determinants of the magnitude of firm-level layoffs. In particular, we find that increase in trade liberalization is associated with more layoffs at the firm level. We estimate that, all else equal, one percent increase in trade liberalization (measured as the ratio between 3-year lagged and current tariffs) translates into 50 percent increase in firm-level layoffs. In addition, we find that trade liberalization results in a decrease in the export productivity cutoff and in an increase (but smaller in absolute value) in the zero-profit productivity cutoff for domestic production.

All of the above results are in accordance with the theoretical predictions of the heterogeneous firms model. However, while, throughout most of the paper, we follow Melitz's framework quite closely, in the empirical analysis we also incorporate several intuitive labor market interactions that are not captured in the structural model but further improve the performance of Melitz's theory. In particular, first, we allow for firm size (in terms of employment), in addition to the productivity, to separately affect layoffs. While we do not find that not controlling for firm size leads to significant biases in the structural parameters, we do capture the fact that larger firms lay off more workers, which is in accordance with our priors. Second, our empirical analysis suggest that higher labor costs are associated with lower probability to suffer from trade-induced layoffs. A possible explanation is that better paid workers might have more human capital and represent firms in industries in which the US has comparative advantage.

Finally, probably the most intriguing empirical finding is that, all else equal, more productive firms suffer fewer layoffs, which is against the theoretical prediction that the relationship between total factor productivity (TFP) and layoffs should be positive. In order to reconcile theory and empirics, we decompose the effects of productivity by firm type, i.e. exporters vs. non-exporters. Our (intuitive) hypothesis is that, even though theory predicts that, regardless or their export status, more productive firms should lay off more workers, this is not the case for exporters. Instead of laying off workers who produce for the domestic market and hiring workers for the foreign market, exporting firms end up with net hires (as we show formally below). Firms that are exporters just shift part of their production, along with the accompanying labor force, from domestic market production to foreign market production. The corresponding empirical specification supports our hypothesis. In particular, once we decompose the productivity effects on layoffs by firm's export status, we find that the relationship is positive for non-exporters, as suggested by the theoretical model, but it is negative for exporters, in accordance with our empirical hypothesis.

The remainder of the paper is structured as follows. In section 2, we develop the theoretical model and we discuss its properties and implications. Section 3 presents the empirical analysis. Section 4 concludes.

2 Theoretical Setting

Our theoretical exposition follows Melitz (2003), however, we concentrate on the labor market implications of the model. In particular, we analyze the effects of productivity, trade liberalization and their interactions on trade-induced, firm-level layoffs.

2.1 Autarky Equilibrium

Consumption. The representative consumer enjoys a continuum of goods indexed by ω, and her utility takes a CES functional form: $U = \left[\int_{\omega\epsilon\Omega} q(\omega)^{\rho} d\omega\right]^{\frac{1}{\rho}}$, where $q(\omega)$ denotes consumption of variety ω, Ω is the mass of potentially available goods, and $\sigma = 1/(1-\rho) > 1$ is the elasticity of substitution between varieties. Consumer's total utility can be thought of as obtained from consumption of an aggregate good, $U \equiv Q$, which is composed of different varieties, with a corresponding aggregate price index $P = \left[\int_{\omega\epsilon\Omega} p(\omega)^{1-\sigma} d\omega\right]^{\frac{1}{1-\sigma}}$. Making use of the definitions of aggregate consumption and the CES price index, we solve the representative consumer's problem to obtain demand, $q(\omega) = Q\left[\frac{p(\omega)}{P}\right]^{-\sigma}$, and expenditure, $r(\omega) = R\left[\frac{p(\omega)}{P}\right]^{1-\sigma}$, for each variety ω, where $R = PQ = \int_{\omega\epsilon\Omega} r(\omega) d\omega$ denotes aggregate expenditure.

Production. There is a continuum of firms, and each of them produces a different variety ω. Production technology requires only labor and is subject to $l = f + q/\varphi$. All firms pay the same fixed cost f, but have different productivity levels $\varphi > 0$.[3] Given the demand for its product, each firm maximizes its profits by setting the price of its variety as a mark-up over marginal cost: $p(\varphi) = \frac{1}{\rho\varphi}$, where the wage rate is normalized to one. Thus, firm revenues can be expressed as $r(\varphi) = R(P\rho\varphi)^{\sigma-1}$, so that the ratio of any two firms' revenues only depends on their productivities $r(\varphi_i)/r(\varphi_j) = (\varphi_i/\varphi_j)^{\sigma-1}$.

[3] Thus, each variety ω can be uniquely mapped to a single productivity level φ.

Furthermore, firm profits, $\pi(\varphi) = \frac{r(\varphi)}{\sigma} - f$, and labor demand, $l(\varphi) = f + \frac{\sigma-1}{\sigma} r(\varphi)$, can also be expressed as functions of productivity.

Entry. There is a large pool of potential entrants who are identical prior to entry. In order to produce, firms must pay a fixed entry cost $f_e > 0$, which is sunk. After entry, firms draw their productivity φ from a distribution $g(\varphi)$, with a cumulative distribution $G(\varphi)$. If a firm has a low productivity draw, it exits immediately. Firms that decide to produce face an exogenous probability of death δ in each period. As the productivity level of a firm does not change throughout its lifetime, its optimal per-period profit level remains constant as well. Thus, if a firm's profits are negative upon entry, the firm will exit immediately. 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, φ^a, needed for a firm to stay in the market. Any firm with productivity level $\varphi < \varphi^a$ will exit immediately, and the productivity distribution of the firms that stay in the market will 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 $\tilde{\varphi}$ as a function of the cut-off level φ^a,[4] and also allows to express average revenues as a function of φ^a, $r(\tilde{\varphi}) = \left[\frac{\tilde{\varphi}(\varphi^a)}{\varphi^a}\right]^{\sigma-1} \sigma f$.

Free entry implies that new firms will join the industry as long as the average profit in the sector is positive. Let M denote the equilibrium number of firms that ensures that economic profits are competed away.[5] In equilibrium, aggregate variables such as the CES price index P and the aggregate expenditure R can be expressed in terms of the equilibrium number of firms and the average productivity so that $P = M^{\frac{1}{1-\sigma}} p(\tilde{\varphi}) = M^{\frac{1}{1-\sigma}} \frac{1}{\rho\tilde{\varphi}}$, and $R = Mr(\tilde{\varphi})$, respectively. This enables us to express firm revenues in autarky as a function of the zero-profit productivity cutoff $r(\varphi) = \sigma f \varphi^{\sigma-1} \left(\frac{1}{\varphi^a}\right)^{\sigma-1}$. Consequently, we obtain the equilibrium number of workers employed by firm with productivity φ in autarky as:

$$l^a = f + (\sigma - 1) f \left(\frac{1}{\varphi^a}\right)^{\sigma-1} \varphi^{\sigma-1}. \tag{2.1}$$

According to (2.1), more productive firms will employ more workers. Intuitively, more productive firms enjoy larger market shares and, therefore, need and employ more workers.

[4]More specifically, $\tilde{\varphi}(\varphi^a) = \left[\frac{1}{1-G(\varphi^a)} \int_{\varphi^a}^{\infty} \varphi^{\sigma-1} g(\varphi) d\varphi\right]^{\frac{1}{\sigma-1}}$. As shown in Melitz (2003), $\tilde{\varphi}$ is also the average productivity level for the firms that choose to produce and stay in the market.

[5]See Melitz (2003) for the properties of the equilibrium and details on aggregation.

2.2 Costly Trade

The world consists of $n+1 \geq 2$ identical countries.[6] Domestic firms may export their products to any country after they pay a fixed export cost, $f_x > 0$ (in addition to the fixed cost, f, which they still must incur to produce domestically). The decision to export is made after each firm draws its productivity level. Firms that export serve the domestic market as well.

Regardless of their export status, all firms pay the same overhead production cost. In addition, exporting firms face higher marginal cost for their exports due to ad-valorem tariffs, t, which are assumed to be symmetric across all trading partners. Thus, each firm's domestic pricing rule is defined as before, $p_d(\varphi) = 1/\rho\varphi$, while export prices are $p_x(\varphi) = (1+t)p_d(\varphi) = (1+t)/\rho\varphi$, where subscript d stands for 'domestic,' and subscript x stands for 'export.' Price separability translates into separability of exporting firms' revenues: $r(\varphi) = r_d(\varphi)$, if a firm is selling only domestically; and $r(\varphi) = r_d(\varphi) + nr_x(\varphi) = [1 + n(1+t)^{1-\sigma}]r_d(\varphi)$, if a firm is exporting. Furthermore, and exporting firm's profits can be split into their domestic, $\pi_d(\varphi)$, and foreign, $n\pi_x(\varphi)$, portions. Finally, each exporting firm's labor demand, $l^{ct}(\varphi) = l_d^{ct}(\varphi) + nl_x^{ct}(\varphi)$, can also be decomposed into its domestic, $l_d^{ct} = f + r_d(\varphi)\frac{\sigma-1}{\sigma}$, and exporting, $l_x^{ct} = f_x + r_x(\varphi)\frac{\sigma-1}{\sigma}$, portions, where superscript ct denotes 'costly trade.'

As in the autarky equilibrium, there is a large pool of potential entrants and firms with negative domestic profits will exit immediately. In addition, however, some firms will also choose to export, as long as their productivity draw is high enough to allow them to realize non-negative profits from exports. This means that there will be two zero-profit productivity cutoff conditions: one for domestic profits, $\pi_d(\varphi^{ct}) = 0$, which determines the lowest productivity draw, φ^{ct}, needed for a firm to stay in business; and one for export profits, $\pi_x(\varphi_x^{ct}) = 0$, which determines the lowest productivity draw, φ_x^{ct}, 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, φ_x^{ct}, needed for profitable exports is necessarily higher than the lowest productivity threshold, φ^{ct}, needed for domestic production. See Figure 1. In addition, the minimum productivity draw needed for domestic pro-

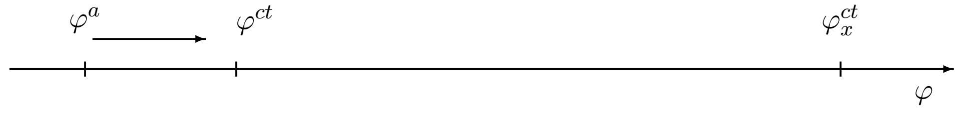

Figure 1: Firm Productivity and Costly Trade

[6]Thus, each country has $n \geq 1$ potential trading partners, and all countries share the same wages and same aggregate variables.

duction must increase once the country opens to trade. The intuition is that when some domestic firms start exporting, their market shares increase. As a result their demand for resources increases and this bids up real wage. Consequently, some of the least productive domestic firms are driven out of the market and there is an increase in the average productivity level and in the zero-profit productivity cutoff for domestic production.

Our analysis of employment in the trade equilibrium resembles the closed economy case, but this time we use the average domestic productivity level $\tilde{\varphi}$ and the average export productivity level $\tilde{\varphi}_x$.[7] First, we express average revenues and aggregate variables in terms of the zero-profit productivity cutoffs, then we 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:

$$l^{ct} = f + (\sigma - 1) f \left(\frac{1}{\varphi^{ct}} \right)^{\sigma - 1} \varphi^{\sigma - 1}. \tag{2.2}$$

The only difference between (2.1) and (2.2) is that the zero domestic profit productivity threshold is higher in the trade equilibrium ($\varphi^{ct} > \varphi^a$). The equilibrium number of workers employed by an exporting firm is:

$$l^{ct} = \underbrace{f + (\sigma - 1) f \left(\frac{1}{\varphi^{ct}} \right)^{\sigma - 1} \varphi^{\sigma - 1}}_{\textbf{domestic}} + \underbrace{n f_x + (\sigma - 1) f \left(\frac{1}{\varphi^{ct}_x} \right)^{\sigma - 1} n (1+t)^{1-\sigma} \varphi^{\sigma - 1}}_{\textbf{export}}, \tag{2.3}$$

where, following the theoretical implications of the model, we decompose total employment in the exporting firms into workers who produce for the domestic market (term labeled 'domestic'), and workers who produce exports (term labeled 'export').

The difference between the equilibrium number of workers employed in each firm in autarky, defined in equation (2.1), and the corresponding number of workers employed by the same firm in the trade equilibrium, defined in equations (2.2) and (2.3) (depending on the firm's type), obtains the change in firm-level employment caused by trade. For firms that only sell domestically, it is:

$$l^a - l^{ct} = (\sigma - 1) f \left[\left(\frac{1}{\varphi^a} \right)^{\sigma - 1} - \left(\frac{1}{\varphi^{ct}} \right)^{\sigma - 1} \right] \varphi^{\sigma - 1}. \tag{2.4}$$

(2.4) implies that the number of workers employed in a firm that only sells domestically will be lower in the trade equilibrium (as φ^{ct} is larger than φ^a). These firms will lay off

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

workers when the country opens to trade. The change in employment for the exporters is:

$$l^a - l^{ct} = \underbrace{(\sigma-1)f\left[\left(\frac{1}{\varphi^a}\right)^{\sigma-1} - \left(\frac{1}{\varphi^{ct}}\right)^{\sigma-1}\right]\varphi^{\sigma-1}}_{\textbf{domestic(layoffs)}} - \underbrace{nf_x - (\sigma-1)f\left(\frac{1}{\varphi^{ct}}\right)^{\sigma-1} n(1+t)^{1-\sigma}\varphi^{\sigma-1}}_{\textbf{export(hires)}} \quad (2.5)$$

Opening to trade has two opposing effects on employment for the exporting firms. First, just like in the case of firms that do not export, the number of workers involved in production for the domestic market will be inversely affected by trade. This is captured by the positive, first term 'domestic(layoffs)' in (2.5). Note that this term, and the corresponding effect, is identical to the total effect on employment for firms that sell only domestically. Second, the number of workers involved in production of exports will increase (from zero in autarky). This is captured by the negative, second term 'export(hires)' in (2.5). The net effect on employment for the exporting firms when a country opens from autarky to trade is ambiguous and depends on the firm's productivity level. When the country is exposed to trade the exporters face a trade off between increase in revenues and increase in fixed costs due to additional export cost. Melitz (2003) shows the most productive export firms increase their profit and market share whereas the less productive exporters increase their market share but are subject to profit loss. Consequently, there are net hires for firms who realize an increase profits and net layoffs for firms who realize a drop in profits.

While interesting from a theoretical perspective, the above analysis is empirically irrelevant, as we rarely observe a move from autarky to trade.[8] Most of the time, countries experience trade liberalization. In particular, intense liberalization is what happened in the US economy, which is the subject of our study, during the period of investigation 1980-2005. Therefore, in the next section, we derive and discuss the effects of trade liberalization on the labor market, and we quantify these effects in our empirical analysis.

[8] A couple of notable exceptions, as noted by Feenstra and Taylor (2008), include the aftermath of the US embargo in the early 1800s, and the opening of the Japanese economy to trade during 1850s. A more recent example of a country that rapidly opened its borders to trade with the rest of the world is Mexico. In the mid 80s, Mexico slashed its tariffs (and other trade barriers) as part of its accession into the General Agreement on Trade and Tariffs (GATT). During the 90s, this country signed a very important free trade agreement (FTA) with US and Canada, (NAFTA). In addition, during the same period, Mexico entered into series of FTAs with other Latin American nations, as well as with Israel and with the European Union in 2000.

2.3 Trade Liberalization

Qualitatively, the effects of trade liberalization are identical to the effects of opening to trade. Figure 2 depicts the changes in the zero-profit productivity cutoffs (both domestic and export) in response to trade liberalization. The export productivity

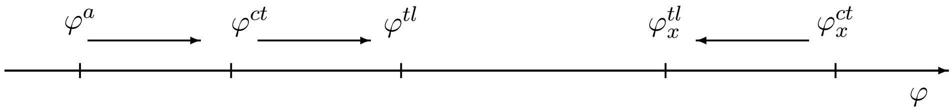

Figure 2: Firm Productivity and Trade Liberalization

cutoff decreases from φ_x^{ct} to φ_x^{tl} because, due to lower export costs,[9] firms with lower productivity levels now find it profitable to export. More exporters increase labor demand and bids up real wages. This results in market share losses, accompanied by layoffs, for some domestically producing firms. In addition, the least productive firms are forced to exit, which leads to an increase in the minimum threshold needed for domestic production (from φ^{ct} to φ^{tl}). Theory allows us to further formalize the relationship between the zero domestic productivity cutoff and the export productivity cutoff in the following proposition.[10]

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:*

$$\left|\frac{\varphi^{ct}-\varphi^{tl}}{\varphi^{ct}}\right| < \frac{\varphi_x^{ct}-\varphi_x^{tl}}{\varphi_x^{ct}}.$$

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

Proof is in the Appendix. Intuitively, 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.

[9]The model assumes symmetric trade liberalization, so that any decrease in domestic protection is matched by an equivalent decrease in foreign protection, with symmetric effects on foreign firms.

[10]In the empirical analysis, we use the predictions of this proposition to translate changes in the export productivity cutoff into changes in the domestic productivity cutoff.

Following the steps of the derivation of firm-level employment outcomes when the economy moves from autarky to trade, we can express the number of workers laid off due to trade liberalization by the firms that sell only domestically as:

$$l^{ct} - l^{tl} = (\sigma - 1) f \left[\left(\frac{1}{\varphi^{ct}} \right)^{\sigma-1} - \left(\frac{1}{\varphi^{tl}} \right)^{\sigma-1} \right] \varphi^{\sigma-1}. \tag{2.6}$$

The only difference between (2.6) and (2.4) is in the zero productivity thresholds. (2.6) implies that the number of workers employed in a firm that only sells domestically will be lower after trade liberalization took place (as φ^{tl} is larger than φ^{ct}).

The change in employment, due to trade liberalization, for an exporting firm is:

$$\begin{aligned} l^{ct} - l^{tl} \;=\; & \underbrace{(\sigma - 1) f \left[\left(\frac{1}{\varphi^{ct}} \right)^{\sigma-1} - \left(\frac{1}{\varphi^{tl}} \right)^{\sigma-1} \right] \varphi^{\sigma-1} +}_{\textbf{domestic(layoffs)}} \\ & \underbrace{n(\sigma - 1) f_x \left[\left(\frac{1}{\varphi^{ct}} \right)^{\sigma-1} (1 + t^{ct})^{1-\sigma} - \left(\frac{1}{\varphi^{tl}} \right)^{\sigma-1} (1 + t^{tl})^{1-\sigma} \right] \varphi^{\sigma-1},}_{\textbf{export(hires)}} \end{aligned} \tag{2.7}$$

where, trade liberalization is measured by a discrete tariff reduction from t^{ct} to t^{tl}. As in the case of a move from autarky to trade, trade liberalization has two opposing effects on employment for the exporting firms. First, the number of workers involved in production for the domestic market will be inversely affected by trade liberalization. This is captured by the first term 'domestic(layoffs)'. Note that this term, and the corresponding effect, is identical to the total effect on employment for firms that sell only domestically. Second, the number of workers involved in production of exports will increase. This is captured by the negative, second term 'export(hires)' in (2.7). In addition, it can be shown that, with trade liberalization, the second effect unambiguously dominates the first for the firms that are exporters before and after the trade.[11] This implies that there will be net hires in the exporting firms. Furthermore, it is clear from (2.6) and (2.7) that the magnitude of employment changes (both layoffs and hires) is contingent on firm productivity as well. We formalize the effects of trade and production on employment in the following proposition.

Proposition 2.2 *Symmetric trade liberalization with the rest of the world will result in: (a) layoffs for firms that do not export; (b) gross layoffs in the domestic segment*

[11] Note that when the economy opened up to trade from autarky, some less productive exporters suffered a profit loss due to the additional fixed export costs. For firms who have been exporting before and after trade liberalization, this is not an issue because the fixed cost of exporting do not change as a result of trade liberalization.

of the exporters; (c) gross hires in the export segment of the exporters; (d) net hires for the exporting firms. All of the above effects will be stronger for the more productive firms and for more pronounced trade liberalization.

Proof is in the Appendix. The intuition for these results is that once a country opens to symmetric trade liberalization with the rest of the world, firms that export gain net market share and the gain is larger for the more productive exporters. The increase in market share and profits for the exporting firms is associated with more hires and a net increase in employment. The increase in employment is larger for the more productive exporters. Higher labor demand (due to the exports) bids up the price of this input, and forces some of the firms that only produce for the domestic market to exit, while others lose market shares and lay off workers. The bigger (more productive) the losers, the larger the layoffs.

As evident from the analysis so far, theory generates clear and sharp predictions about the effects of trade liberalization and productivity on firm-level employment. Unfortunately, some empirical limitations do not allow us to test the compete set of structural relationships in the model. For example, even though our data set has the unique advantage of measuring *trade-induced* layoffs directly, it does not measure hires due to trade liberalization or due to improved access to (new) foreign markets. Therefore, we will not be able to estimate (2.7). Instead, we will concentrate on the layoffs in the firms that only produce for the domestic market, (2.6), along with the layoffs in the domestic segment of the exporting firms, the first term in (2.7), by estimating the following equation for all firms in our sample:

$$l^{ct} - l^{tl} = (\sigma - 1) f \left[\left(\frac{1}{\varphi^{ct}} \right)^{\sigma-1} - \left(\frac{1}{\varphi^{tl}} \right)^{\sigma-1} \right] \varphi^{\sigma-1}. \tag{2.8}$$

where, $l^{ct} - l^{tl}$ measures trade-induced layoffs, regardless of whether a firm produces only for the domestic market or it also exports.[12]

We address one more empirical issue before we bring our model to the data. Estimating (2.8) directly will provide evidence for the relationship between productivity and trade-induced layoffs, but will say nothing about the relationship between trade liberalization and layoffs. To address this problem, we resort to the theoretical properties of the model. In particular, we employ the two zero-profit cutoff conditions to express the zero-profit domestic productivity cutoff φ^{τ}, $\tau \in \{ct, tl\}$, in terms of tariffs and the corresponding export productivity cutoff φ_x^{τ} as:

$$\varphi^{\tau} = \varphi_x^{\tau} \frac{1}{(1 + t^{\tau})} \left(\frac{f}{f_x} \right)^{\frac{1}{\sigma-1}}. \tag{2.9}$$

[12] In the empirical section we discus the implications of differentiating between the two types of firms.

Plug (2.9) in (2.8) to obtain an expression for the number of layoffs caused by trade liberalization in terms of productivity and trade protection (ad-valorem tariffs):

$$l^{ct} - l^{tl} = (\sigma - 1) f_x \left(\frac{1 + t^{ct}}{\varphi_x^{ct}} \right)^{\sigma - 1} \varphi^{\sigma - 1} - (\sigma - 1) f_x \left(\frac{1 + t^{tl}}{\varphi_x^{tl}} \right)^{\sigma - 1} \varphi^{\sigma - 1} \tag{2.10}$$

(2.10) is the structural base for our empirical analysis of the effects of trade liberalization and productivity on trade-induced layoffs. According to the predictions of Proposition 2.2, we expect to find a positive relationship between trade liberalization and layoffs as well as between productivity and layoffs. We test these relationships next.

3 Empirical Analysis

3.1 Data Description

This study covers the period 1980-2005 and we employ various series of US firm-level and sectoral data. The main advantage of our data is that it allows us to directly identify *trade-induced* losses, in terms of firm layoffs. Our primary data source is the Petition for Trade Adjustment Assistance Database (PTAA), which is constructed and maintained by the Employment and Training Administration of the U.S. Department of Labor.[13] The PTAA data consists of petition series at the 4-digit Standard Industrial Classification (SIC) level including the date when a group of workers files a TAA petition, when and whether the petition was certified, and the estimated number of workers to be laid off by each firm (according to the petition) as an adverse consequence of foreign trade. To measure trade-induced layoffs we only consider petitions that were TAA-certified.[14]

To estimate 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.[15] Following the existing literature, we

[13]A petition may be filed by a group of three or more workers, an employer of a group of workers, a union, and certain other officials. In order to be eligible for trade adjustment assistance, laid of workers need certification as they are adversely affected by foreign trade.

[14]There are some instances in the data, when the same firm files TAA petitions from different 4-digit sectors in the same year. To keep the number of observations as large as possible, we treat such petitions as separate observations in our sample. Accordingly, in our estimations, we cluster the errors by firm and industry. Aggregating the sample to the firm level produces very similar results.

[15]The firm-level variables used in the calculation of TFP include (Compustat labels in parenthesis):

transform our productivity variable in deviations from the mean. This is inconsequential for the significance of our estimates, but eases interpretation. Once we calculate total factor productivity for each firm, we merge these data with the certified firms from the TAA data set. This determines the size of the estimation sample for our main analysis to be 2063 observations.[16]

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. These include: firm-level total employment, labor costs, and export status; and, industry-level data on tariffs and imports. Total employment is measured by total number of employees and taken from Compustat. Labor cost is calculated by multiplying the total number of employees with the average industry wage, which is taken from Bartelsman, Becker, and Gray (2001). We follow Denis *et al.* (2002) who use Compustat's firm-level data series on "Geographic Segment Type" to classify firms as either exporters or non-exporters.

We use tariff data to measure trade liberalization. Even though, non-tariff trade barriers (NTBs) are probably a more significant and relevant measure of trade protection, we choose tariffs for two reasons. First, comprehensive data on NTBs covering the period of investigation are not available. Second, we believe that US 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, later, by the World Trade Organization (WTO), are the more appropriate measure of protection for the current theoretical setting, which assumes symmetric trade liberalization. We use two sources of data on tariffs. Import-weighted average tariffs for the period 1980-1988 are from Bernard *et al.* (2006), and tariff data for the years after 1989 are from the Trade Analysis Information System (TRAINS).[17] In order to keep the sample size as large as possible, we use tariffs at the 3-digit SIC level. In addition, we employ current and 3-year lagged tariffs to measure trade liberalization and to obtain our main estimation results.[18] Data on sectoral imports are also from two sources. Data on imports

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). In addition, we use Bartelsman, Becker, and Gray (2001) to obtain the following industry-level variables: Production Workers, Production Worker Wages, Deflator for value of shipments, Deflator for material costs and Deflator for Investment.

[16]It should be noted that, even though our study covers an extended time span, we will be estimating cross-section econometric specifications, where each observation represents a petition-firm-year combination, and all variables are in real terms.

[17]We accessed TRAINS through the World Bank's World Integrated Trade Solution (WITS) software at http://wits.worldbank.org/witsweb/.

[18]Three years is often viewed in the literature as the average period needed for trade (an other) variables to adjust to trade shocks and policies. In the sensitivity analysis, we experiment with

up to 1989 are from Feenstra (1996), and imports for the years after 1989 are from the United Nations Conference on Trade and Development (UNCTAD) and TRAINS. Summary statistics are reported in Table 2 of the Technical Appendix.

3.2 Estimation Results and Analysis

Our first attempt in testing the theoretical predictions of the model is to estimate a reduced-form linearized version of our structural equation,

$$l^{ct} - l^{tl} = (\sigma - 1) f_x \left(\frac{1 + t^{ct}}{\varphi_x^{ct}} \right)^{\sigma-1} \varphi^{\sigma-1} - (\sigma - 1) f_x \left(\frac{1 + t^{tl}}{\varphi_x^{tl}} \right)^{\sigma-1} \varphi^{\sigma-1}, \tag{3.1}$$

which relates trade-induced, firm-level layoffs to the interaction between firm's productivity and lagged industry tariffs and to the interaction between firm productivity and current tariffs. (3.1) translates into the following econometric specification:

$$LAYOFF_i = \tilde{\alpha}_0 + \tilde{\alpha}_1 L3.T_j * TFP_i + \tilde{\alpha}_2 T_j * TFP_i + \vartheta_j + \varepsilon_{ij}, \tag{3.2}$$

where: $LAYOFF_i$ is the logarithm of the number of trade-induced layoffs in firm i. TFP_i proxies for the term $\varphi^{\sigma-1}$, and measures total factor productivity of firm i. T_j and $L3.T_j$ are the logarithms of current and 3-year lagged ad-valorem tariffs in industry j, which proxy for $(1 + t^{tl})^{\sigma-1}$ and $(1 + t^{ct})^{\sigma-1}$, respectively. Finally, ϑ_j denotes a set of 3-digit SIC industry fixed effects, which we use to control for unobserved sectoral characteristics that may affect trade-induced layoffs but are not explicitly included in the theoretical specification (such as comparative advantage, for example).[19]

In accordance with the predictions of the structural model, we expect the coefficient, $\tilde{\alpha}_1$, in front of the first term, to be positive, implying a direct relationship between the interaction of total factor productivity and lagged tariffs and the number of workers laid-off by each firm due to trade liberalization. The estimate of $\tilde{\alpha}_2$ 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. Finally, since theory suggests that the zero-profit export productivity cutoff falls (from φ_x^{ct} to φ_x^{tl}) due to trade liberalization, we expect $\tilde{\alpha}_1$ to be smaller, in absolute value, than $\tilde{\alpha}_2$. To see this, interpret the two coefficients structurally, as $\tilde{\alpha}_1 = \frac{(\sigma-1)f_x}{(\varphi_x^{ct})^{\sigma-1}}$ and

shorter and longer lags to find that the changes in our results are intuitive, and in accordance with the model's theoretical predictions. Results are also robust to measuring trade liberalization at a more aggregated level.

[19] We choose 3-digit SIC dummies to match the level of tariff aggregation that are used in the interaction variables. An additional advantage of this particular level of sectoral aggregation is that it delivers a representative number of firms from each industry.

$\tilde{\alpha}_2 = -\frac{(\sigma-1)f_x}{(\varphi_x^{tl})^{\sigma-1}}$, respectively. It easy to see now, that $\varphi_x^{ct} > \varphi_x^{tl}$ implies $\tilde{\alpha}_1 < |\tilde{\alpha}_2|$. In addition, we can use the ratio between the two estimates to calculate the percentage change (fall) in the zero-profit export productivity cutoff caused by trade liberalization as:[20]

$$\frac{\varphi_x^{ct} - \varphi_x^{tl}}{\varphi_x^{ct}} = \frac{(-\tilde{\alpha}_2)^{\frac{1}{\sigma-1}} - \tilde{\alpha}_1^{\frac{1}{\sigma-1}}}{(-\tilde{\alpha}_2)^{\frac{1}{\sigma-1}}}. \tag{3.3}$$

As can be seen from the table, the estimates of the coefficients on both terms are significant and have signs and relative magnitude as expected. The interaction between lagged tariffs and productivity has a positive effect on layoffs, while the interaction of current tariffs and productivity has a negative effect on layoffs. In addition, we find that $\tilde{\alpha}_1$ is indeed smaller, in absolute value, as compared to $\tilde{\alpha}_2$. We use (3.3), with $\sigma = 6$, to estimate a significant fall in the zero-profit export productivity cutoff of 7.56% (standard error 4.49). We report this estimate in the bottom panel of Table 1.[21] Combined with the predictions from Proposition 2.1, our estimates imply an increase in the zero-profit domestic productivity cutoff of 7.28%, which however is only marginally statistically significant (standard error 4.50).

According to Melitz's theory, more productive firms will always be larger, as they will have larger market shares, i.e. there should be perfect correlation between productivity and size. Often, this is not the case in reality, where the largest firms (in terms of employment) are not necessarily the most productive ones. The empirical implication is that, even after controlling for productivity, larger (in terms of employment) firms may lay off more workers. To allow for this possibility, in column 2 of Table 1, we estimate equation (3.2) after controlling for firm size, as proxied by the logarithm of total number of employees. We label this variable SIZE. The new results are very similar to the ones obtained without controlling for size. The estimates of $\tilde{\alpha}_1$ and $\tilde{\alpha}_2$ are significant and have the expected signs and relative magnitude. This suggests that not controlling for employment (size) does not have severe consequences for the empirical performance of the model. In addition, we provide empirical support for the hypothesis that larger firms lay off more workers. More specifically, we estimate that, all else equal, one percent increase in total, firm-level employment is associated with 0.13% increase in trade-induced layoffs, which is both statistically and economically significant. Finally, it is worth noting that the changes in the productivity cutoffs, reported in the bottom panel of the table, are now slightly larger in magnitude and more precisely estimated. Overall, these results suggest that productivity and size

[20]Below, we draw inferences based on the standard, for the trade literature, value the elasticity of substitution $\sigma = 6$. To ease interpretation of of our results however, one can think of (3.1) as a semi-structural specification, where the elasticity of substitution σ is set to 2. In this case, the structural model becomes $l^{ct} - l^{tl} = \frac{(\sigma-1)f_x}{\varphi_x^{ct}}(1+t^{ct})\varphi - \frac{(\sigma-1)f_x}{\varphi_x^{tl}}(1+t^{tl})\varphi$.

[21]Standard errors are calculated with the Delta method.

Table 1: Trade Liberalization, Productivity and Layoffs

	(1) BASE	(2) EMPL	(3) IV	(4) POLIT	(5) SLCT	(6) LIBER	(7) EXPRT
L3.T*TFP	17.217	17.209	154.077	149.647	104.224		
	(6.008)**	(5.961)**	(62.944)*	(62.676)*	(22.393)**		
T*TFP	-25.509	-27.412	-226.285	-221.293	-141.373		
	(6.710)**	(6.693)**	(87.892)*	(88.185)*	(33.438)**		
TFP						-1.998	64.756
						(6.906)	(28.575)*
LIBER						49.743	49.658
						(13.324)**	(13.202)**
SIZE		0.130	0.149	0.139	0.164	0.151	0.156
		(0.042)**	(0.056)**	(0.054)*	(0.032)**	(0.033)**	(0.033)**
POLIT				0.185			
				(0.158)			
EXP							69.604
							(29.055)*
TFP*EXP							-69.923
							(29.160)*
Constant	4.310	3.164			3.491	5.017	-57.994
	(0.167)**	(0.376)**			(1.071)**	(6.991)	(28.490)*
SUFFER							
POLIT					-0.250	-0.250	-0.250
					(0.070)**	(0.070)**	(0.070)**
TARIFF					-31.001	-31.001	-31.001
					(2.682)**	(2.682)**	(2.682)**
ΔIMP					0.401	0.401	0.401
					(0.098)**	(0.098)**	(0.098)**
LABOR_COST					-0.037	-0.037	-0.037
					(0.022)+	(0.022)+	(0.022)+
Constant					1.553	1.553	1.553
					(0.832)+	(0.832)+	(0.832)+
Mills Ratio					-1.061	-1.352	-1.324
λ					(0.291)**	(0.278)**	(0.278)**
N	1259	1259	1158	1158	2063	2063	2063
Chi2							
R^2, $Wald-\chi^2$	0.198	0.211			306.57	272.53	282.64
UnderId			11.167	10.506			
OverId			0.965	0.968			
$\%\Delta\varphi_x^{ct}$	-7.56	-8.89	-7.39	-7.52	-5.91		
	(4.49)+	(4.44)*	(1.33)**	(1.38)**	(1.02)**		
$\%\Delta\varphi^{ct}$	7.28	8.61	7.11	7.47	5.56		
	(4.50)	(4.46)+	(1.37)**	(1.39)**	(1.03)**		

Standard errors in parentheses. + $p < 0.10$, * $p < .05$, ** $p < .01$. The dependent variable is always the logarithm of firm layoffs. Estimates of the 3-digit SIC FEs, used in each estimation, are omitted for brevity. Errors in each estimation are clustered by firm and 3-digit SIC industry.

may be not be perfectly correlated as suggested by theory, and that in practice each of these variables may have separate effects on layoffs.

We have good reasons to believe that the OLS estimates presented so far may be biased. The reason is that the covariates from 3.1 are potentially endogenous. For example, as function of labor, TFP is endogenous by construction. Therefore, we need to account for this endogeneity due to simultaneity.[22] In addition, Yotov (2010a) shows that trade-induced unemployment is an important determinant of US trade policy.[23] This implies that our trade variables, especially current tariffs, are endogenous as well. To address the issue of endogeneity, we estimate equation (3.2) using the instrumental variable and general method of moments (IV-GMM) estimator. Our instruments include: lagged productivity, 5-year lagged tariffs, tariffs from the beginning of the period of investigation (1979), the squares of the instruments and their interactions. IV-GMM estimates are reported in column 3 of Table 1.

Before we interpret the results, we make sure that our instruments have the necessary properties to validate the IV estimator. We test for under-identification, which checks whether the instruments are relevant and correlated with the endogenous regressors, and for overidentification, which tests whether our instruments are uncorrelated with the error term. χ^2 statistics from these tests are reported toward the bottom of Table 1. Based on these values, we reject the null (UnderId) hypothesis, which implies that the model is not under-identified, and we fail to reject the null (OverId) hypothesis, meaning that the excluded instruments are correctly excluded from the estimated equation.

Two properties of the IV-GMM estimates stand out. First, they imply that not accounting for endogeneity causes severe biases. Both $\tilde{\alpha}_1$ and $\tilde{\alpha}_2$ are significantly larger in absolute value as compared to their OLS counterparts. Second, the IV estimates of the changes in the productivity cutoffs are smaller, however, more precisely estimated than the OLS numbers from columns 1 and 2. We estimate both a significant decrease in the export productivity cutoff of 7.39% (standard error 1.33) and a significant increase of 7.11% (standard error 1.37) in the domestic productivity cutoff.

The fact that we are investigating the effect of trade liberalization on labor layoffs

[22] TFP might also be related to trade liberalization. For example, Bustos (2006) finds that increased export opportunities can have a positive influence on firm performance. She shows that a fall in trading partners' tariffs increases revenues for exporters, who in turn adopt new technologies profitable for more firms. Konings and Vandenbussche (2008) conduct an empirical study about the effects of anti-dumping protection on the productivity of domestic, import-competing firms and find that firms that receive protection improve their productivity. Pavcnik (2002) uses data on Chilean plants and finds evidence that productivity increases after trade liberalization for plants in the import competing sector.

[23] Furthermore, Yotov (2010b) estimates that, when choosing the level of sectoral trade protection, the US government attaches four times more weight to the welfare of trade-affected workers.

only for the firms that are labeled as suffering from trade, implies that our results may be subject to a selection bias, which means that 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:

$$LAYOFF_i = \alpha_0 + \alpha_1 L3.T_j * TFP_i + \alpha_2 T_j * TFP_i + \varepsilon_{1ij}, \tag{3.4}$$

where a layoff is observed if:

$$\gamma_0 + \gamma_1 EXCL_i + \gamma \mathbf{X_{ij}} + \varepsilon_{2ij} > 0. \tag{3.5}$$

Here, ε_{1ij} and ε_{2ij} are correlated and jointly normally distributed. Equation (3.5) 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 $\mathbf{X_{ij}}$ 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 (3.5) include: the level of sectoral trade protection proxied by industry tariffs, TARIFF; the change in imports, Δ IMP, which is the key variable used by the government in the determination of TAA-certification outcomes and firm-level labor costs, LABOR_COST.

Finding a good exclusionary variable is crucial for sound econometric results in a selection model. Fortunately, a closer look into the Petition for Trade Adjustment Assistance data, which we use to measure firm-level trade-induced unemployment, gives us an excellent opportunity to construct a good exclusionary variable. In order to get TAA, laid-off employees have to go through a formal process of certification, where the government determines whether a firm is really affected by trade or suffers for any other reason, and verifies whether a group of workers are laid off due to trade related problems. Given the unified federal TAA certification procedures, one would expect that if two firms produce identical products and one of them is TAA-certified, the other should also be eligible to enter the program. Surprisingly, this is not the case. There are instances in the data when, even branches of the same company, producing identical products *but operating in different states*, have different outcomes when applying for TAA. This suggests that there might be some state characteristic that affects government's decision to grant TAA, which in turn we could use to identify our selection model.

Influenced by the large success of the political economy literature of trade and protectionism, we thought that overall political affiliation of a firm's state might be a good indicator of the firm's chances for TAA-certification. At the same time, whether a state is blue or red should not be related to any firm's performance, and trade-induced layoffs, in particular. Thus, we identify the political orientation of the state for each firm in our sample (based on the results in the election year preceding the petition year from our data) and use it as an exclusionary variable in the selection model (3.4)-(3.5). We assign a value of one to the exclusionary variable, POLIT, if a state is classified as republican.

To check whether our exclusionary variable has any explanatory power in the structural equation (3.4), we first re-estimate the specification from column (3) with POLIT as an additional covariate. As can be seen from column 4 of Table 1, we find no significant correlation between the political affiliation of a state and the number of workers laid off due to trade by a firm operating in this state. This is supported by the insignificant coefficient on POLIT. In addition, the signs, magnitude and significance of the other explanatory variables do not change.[24] Overall, these results suggest that POLIT might be a good exclusionary variable for our selection model, as long as it is a significant predictor of the probability for TAA certification. We check this next.

Maximum Likelihood Estimation (MLE) results from the Heckman selection specification (3.4)-(3.5) are reported in column 5 of Table 1. We start with analysis of the selection equation. First, and most importantly, we see that the coefficient on POLIT in the first stage equation is significant. This, in combination with a significant estimate of the Mills λ = -.868 (standard error 0.284), reported toward the bottom of column 5, shows that the selection equation and the main equation are not independent. 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.[25] More importantly, the estimate on POLIT is significant, which reinforces our hypothesis that it is a good exclusionary variable indeed. The negative sign of the coefficient estimate of TARIFF is expected: Higher level of tariffs are associated with lower probability to enter the TAA program. The intuition is that higher tariffs result in less imports and less lost market shares for the domestic firms, which, in turn, lay off fewer workers. Increase in imports increases the probability for TAA certification. This is captured by the positive and significant estimate of the coefficient on ΔIMP, and should not be surprising because, as mentioned earlier, import changes are key determinants of TAA- certification outcomes. The negative and significant coefficient on $LCOST$ indicates that higher labor costs are associated with lower probability to suffer from trade-induced layoffs and, therefore, qualify for TAA. A possible explanation is that better paid workers might have more human capital and represent firms in industries in which the US has comparative advantage.

[24]It is possible that political affiliation of a state is associated with trade protection for the main state industry. This explains the small changes in the magnitude of the estimates.

[25]This, 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. POLIT meets our needs.

Next, we turn to the main (second-stage) estimation results, which are obtained after controlling for selection (and for endogeneity as well). Qualitatively, the new findings are very similar to the IV-GMM results presented in column 3, which only control for endogeneity, and to the OLS estimates from the first two columns of the table. The estimated 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. In addition, the estimate of α_1 is smaller, in absolute value, as compared to the estimate of α_2. Quantitatively the 'selection' estimates are significantly smaller than their IV counterparts. This suggests that the bias when selection is not controlled for is upward and significant. Finally, in terms of cutoff changes, we find that the selection specification, which also controls for endogeneity, produces the smallest, but most precisely estimated, changes of -5.91% (standard error 1.02) and 5.56% (standard error 1.03) in the export and the domestic cutoff, respectively.

In our next experiment, we use alternative (1-year and 5-year) tariff lags. Results are omitted for brevity, but are available upon request. In each case, the estimates of $\tilde{\alpha}_1$ and $\tilde{\alpha}_2$ have the expected signs and are significant. Worthy of note, however, is the comparison between the changes in the productivity cutoffs obtained with different lags. We estimate a fall of 1.58% (standard error 1.75) in the export productivity cutoff with the 1-year tariff lags.[26] On the other hand, we find a significant corresponding fall of 11.49% (standard error 0.86) with the 5-year lagged tariffs. These results are in accordance with theory, as, on average, longer time horizons are associated with more liberalization and, therefore, more more pronounced consequences. Importantly, our findings indicate that current layoffs may be associated with lagged trade liberalization and increased import competition over a wide time horizon. This result has implications for the design of the trade adjustment assistance certification procedure.

So far, our empirical findings are in perfect accordance with the theoretical predictions of the structural model. In particular, across all specifications, the estimates are always significant and with signs as expected. In addition, the relative magnitude of the estimates supports the structural prediction of falling zero-profit export productivity cutoff, which we also translated into an increasing (but by less) zero-profit domestic productivity cutoff. While encouraging, in terms of their statistical significance and relative magnitude, the findings from the first five columns of Table 1 do not allow us to directly decompose the effects of productivity and trade liberalization on layoffs. In particular, according to Proposition 2.2, we expect to find a positive correlation between both trade liberalization and layoffs as well as between productivity

[26] We were not surprised to find that the change in the export productivity cutoff was not significant with 1-year lagged tariffs. This finding confirms the general belief that trade (and other) variables need more time to respond to trade shocks and policies.

and layoffs.

We test the relationship between productivity and layoffs in two different ways. First, we use the estimates from column 5 (our most preferred specification), along with the mean of lagged and current tariffs, to estimate the effect of productivity on layoffs as:

$$\frac{\partial LAYOFF_i}{\partial TFP_i} = \widehat{\alpha_1}\overline{L3.T} + \widehat{\alpha_2}\overline{T}, \tag{3.6}$$

where $\overline{L3.T}$ and $\overline{T}$ are the weighted average levels of the 3-year lagged $L3.T_j$'s and the current T_j's, respectively, across all sectors. To construct the tariff means, we use import values as weights. The result is surprising. We estimate the effect of productivity on layoffs to be negative and significant, $\frac{\partial LAYOFF_i}{\partial TFP_i} = -.91$ (standard error .289). However, theory predicts a positive relationship between productivity and layoffs for the firms in our sample. To confirm this puzzling finding, we use an alternative specification of our structural equation (3.1), which we express as:

$$l^{ct} - l^{tl} \;=\; (\sigma - 1) f_x \left[\left(\frac{1 + t^{ct}}{\varphi_x^{ct}} \right)^{\sigma - 1} - \left(\frac{1 + t^{tl}}{\varphi_x^{tl}} \right)^{\sigma - 1} \right] \varphi^{\sigma - 1}. \tag{3.7}$$

(3.7) translates into the following econometric specification:

$$LAYOFF_i = \beta_0 + \beta_1 LIBER_j + \beta_2 TFP_i + \beta_3 SIZE_i + \vartheta_j + \epsilon_{ij}, \tag{3.8}$$

where, $LAYOFF_i$ and TFP_i are defined as before. $SIZE_i$ is the logarithm of total, firm-level employment. ϑ_j is the set of 3-digit SIC fixed effects. Finally, $LIBER_j$ proxies for trade liberalization, and is constructed as the difference between the logarithms of 3-year lagged and current ad-valorem tariffs in industry j. In accordance with our theory, we expect the estimate of β_1 to be positive, indicating that trade liberalization causes layoffs, and the estimate of β_2 to be positive as well, capturing the direct relationship between productivity and layoffs.

Estimates of (3.8), obtained after simultaneously controlling for selection and endogeneity, are reported in column 6 of Table 1.[27] Several properties stand out. First, as before, we find that larger firms, in terms of employment, lay off more workers. The estimate on $SIZE$ is positive, significant and very similar in magnitude to the previous results. Second, as predicted by theory, more trade liberalization is associated with more layoffs. This is captured by the positive and significant estimate of the coefficient on $LIBER$. Given our definition of this variable, the estimate on $LIBER$ implies that one percent increase in the ratio between 3-year lagged and current tariffs

[27] Results obtained with alternative estimators (e.g., IV or OLS) are similar and are available upon request.

is associated with about 50 percent increase in firm-level layoffs. Finally, even though theory predicts that $\widehat{\beta}_2$ should be positive, we estimate the coefficient on TFP to be negative, as suggested by our previous findings, but not significant.

Why do not data conform with theory? Next, we provide (and test) a possible, intuitive explanation. Our hypothesis is that the direction of the relationship between productivity and trade-induced layoffs is contingent upon firms' export status. In particular, we suspect that, in reality, more productive exporters lay off less workers. The reason is that rather than, as suggested by theory, laying off workers who produce for the domestic market and then hiring workers to produce exports, it is very plausible that, in practice, exporters are just shifting part of their production, along with the accompanying labor force, from serving the domestic to serving the foreign market. Proposition 2.2 states that more productive exporters will have more *net* hires, which, in line with the current discussion, implies that more productive exporters will probably suffer less trade-induced layoffs.

To test our hypothesis, we extend specification (3.8). In particular, we introduce a dummy variable, EXP_i, which takes a value of one for exporters, and an interaction term between the export status dummy and firm productivity, $EXP_i{*}TFP_i$, which will allow us to decompose productivity effects by firm type.[28] Thus, the new econometric specification becomes:

$$LAYOFF_i = \gamma_0+\gamma_1 LIBER_j+\gamma_2 TFP_i+\gamma_3 SIZE+\gamma_4 EXP_i+\gamma_4 EXP_i{*}TFP_i+\vartheta_j+\zeta_{ij}, \tag{3.9}$$

Results from the estimation of (3.9) are reported in the last column of Table 1.[29] The findings are in accordance with our expectations and hypothesis. In particular, we see that the relationship between productivity and trade-induced layoffs is positive for the firms that only sell domestically. This is captured by the positive and significant estimate of the coefficient on TFP_i, and is as predicted by the theoretical model. In addition, we estimate a negative and significant relationship between productivity and layoffs for the exports. This supports our intuitive, empirical hypothesis that, rather than laying off workers for domestic production and hiring new workers for exports, exporters just shift labor internally. Finally, we see that the estimates of $SIZE$ and $LIBER$ are not affected by the introduction of the new control variables. This suggests that, regardless of their export status, larger firms lay off more workers

[28] As noted in the data section, we follow Denis *et al.* (2002) who use the series "Geographic Segment Type" from Compustat in order to classify a firm as an exporter. In accordance with theory, our data reveals than many (in fact the majority) of the firms who layoff workers due to trade are indeed exporters.

[29] To estimate (3.9), we simultaneously control for endogeneity and selection.Breaking the sample by firm type and estimating two separate systems produces very similar results. We prefer the estimates obtained with the aggregate sample because those are more efficient.

due to trade, and also that trade liberalization affects both exporters and domestic producers equally on the domestic market. This is encouraging evidence in support of the general predictions of the firm-heterogeneity theory.

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 threefold: First, concentrating on the labor market implications of the Melitz (2003) model, and using data that enables us to measure directly firm-level layoffs caused by trade, we quantify the relationships between productivity, trade liberalization and trade-induced layoffs. 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. Finally, by incorporating intuitive labor market interactions that are not explicitly captured in Melitz's model, we reconcile some discrepancies between theory and empirics and we open avenues for further theoretical work.

Overall, our empirical findings are in accordance with the theoretical predictions of the model. In particular, we find that increase in trade liberalization is associated with more layoffs at the firm level. In addition, we estimate decrease in the export productivity cutoff and an increase (but smaller in absolute value) in the zero-profit productivity cutoff for domestic production, when a country liberalizes its trade policy. An interesting, and puzzling, empirical result is that, contrary to the theoretical predictions, more productive firms lay off fewer workers, all else equal. We reconcile theory and empirics by allowing for different productivity effects across exporters and non-exporters. The new estimations support the empirical hypothesis that more productive exporters lay off less workers, while the relationship between productivity and layoffs is positive and significant for the domestically producing firms, which is in accordance with theory.

An interesting extension of our paper will be to test whether and how our findings differ for industries with comparative advantage as opposed to industries with comparative disadvantage. For example, Bernard *et al.* (2007), extend Melitz's (2003) model to allow 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 comparative disadvantage industries exhibit net job destruction while comparative advantage industries experience net job creation. Our data allows for various tests of their model, depending on industry type.

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Mathematical Appendix

Proof of Proposition 2.1 Apply the relationship in equation (2.9) to trade liberalization to show that $\left|\frac{\varphi^{ct}-\varphi^{tl}}{\varphi^{ct}}\right| = \frac{\varphi_x^{ct}-\varphi_x^{tl}\frac{1+t^{ct}}{1+t^{tl}}}{\varphi_x^{ct}}$. (We use this expression in the empirical section of the text to translate the changes in the export cutoffs into changes in the domestic cutoffs.) 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, $\frac{\varphi_x^{ct}-\varphi_x^{tl}\frac{1+t^{ct}}{1+t^{tl}}}{\varphi_x^{ct}} = \left|\frac{\varphi^{ct}-\varphi^{tl}}{\varphi^{ct}}\right| < \frac{\varphi_x^{ct}-\varphi_x^{tl}}{\varphi_x^{ct}}$.

Proof of Proposition 2.2 Parts (a) and (b): Using Equation 2.2 for l^{ct} and its counter part for l^{tl} we can express the change in labor as:

$$l^{ct} - l^{tl} = (\sigma-1)f\left[\left(\frac{1}{\varphi^{ct}}\right)^{\sigma-1} - \left(\frac{1}{\varphi^{tl}}\right)^{\sigma-1}\right]\varphi^{\sigma-1} \tag{4.1}$$

We know from theory that the zero profit productivity cutoff for domestic production increases after a country moves from costly trade to liberalized trade:

$$\begin{aligned}
\varphi^{tl} &> \varphi^{ct} \\
\left(\frac{1}{\varphi^{tl}}\right)^{\sigma-1} &< \left(\frac{1}{\varphi^{ct}}\right)^{\sigma-1} \\
0 &< \left(\frac{1}{\varphi^{ct}}\right)^{\sigma-1} - \left(\frac{1}{\varphi^{tl}}\right)^{\sigma-1} \\
0 &< (\sigma-1)f\left[\left(\frac{1}{\varphi^{ct}}\right)^{\sigma-1} - \left(\frac{1}{\varphi^{tl}}\right)^{\sigma-1}\right]\varphi^{\sigma-1} = l^{ct} - l^{tl} \qquad (4.2)
\end{aligned}$$

The positive sign indicates that the number of workers employed under costly trade was higher than the number of workers employed under trade liberalization, i.e. there have been labor layoffs for domestic production. Additionally more liberalization will imply a larger discrepancy between the zero profit productivity cutoffs, and hence a higher number of layoffs. Also, taking the derivative of equation 4.1 with respect to φ:

$$\frac{\partial(l^{ct} - l^{tl})}{\partial\varphi} = (\sigma-1)^2 f\left[\left(\frac{1}{\varphi^{ct}}\right)^{\sigma-1} - \left(\frac{1}{\varphi^{tl}}\right)^{\sigma-1}\right]\varphi^{\sigma-2} > 0, \tag{4.3}$$

we find that if a firm is more productive it lays off more workers.

Part (c): For the change in labor for export production:

$$\begin{aligned}
nl_x^{ct} - nl_x^{tl} &= nr_x^{ct}(\varphi)\frac{\sigma-1}{\sigma} - nr_x^{tl}(\varphi)\frac{\sigma-1}{\sigma} \\
&= n(1+t^{ct})^{1-\sigma} r_d^{ct}(\varphi)\frac{\sigma-1}{\sigma} - n(1+t^{tl})^{1-\sigma} r_d^{tl}(\varphi)\frac{\sigma-1}{\sigma} \qquad (4.4) \\
&= n(1+t^{ct})^{1-\sigma}(\sigma-1) f_x \left(\frac{1+t^{ct}}{\varphi_x^{ct}}\right)^{\sigma-1} \varphi^{\sigma-1} \\
&\quad - n(1+t^{tl})^{1-\sigma}(\sigma-1) f_x \left(\frac{1+t^{tl}}{\varphi_x^{tl}}\right)^{\sigma-1} \varphi^{\sigma-1} \\
nl_x^{ct} - nl_x^{tl} &= n(\sigma-1) f_x \left[\left(\frac{1}{\varphi_x^{ct}}\right)^{\sigma-1} - \left(\frac{1}{\varphi_x^{tl}}\right)^{\sigma-1}\right] \varphi^{\sigma-1} \qquad (4.5)
\end{aligned}$$

By using the relationship $\varphi_x^{tl} > \varphi_x^{tl}$, we can conclude that $nl_x^{ct} - nl_x^{tl} < 0$, i.e. there are gross hires for export production. Similar to the previous part we see that more liberalization will imply a larger change in the zero profit export cutoff and more labor hires. Taking the derivative of equation 4.5 with respect to φ:

$$\frac{\partial(l^{ct} - l^{tl})}{\partial\varphi} = n(\sigma-1)^2 f_x \left[\left(\frac{1}{\varphi_x^{ct}}\right)^{\sigma-1} - \left(\frac{1}{\varphi_x^{tl}}\right)^{\sigma-1}\right] \varphi^{\sigma-2} < 0, \qquad (4.6)$$

we find that the more productive export firms will be hiring more workers.

Part (d): To see the overall effect of trade liberalization on labor layoffs for exporters:

$$\begin{aligned}
l^{ct} - l^{tl} &= \frac{\sigma-1}{\sigma}\left[1+n(1+t^{ct})^{1-\sigma}\right] r_d^{ct}(\varphi) - \frac{\sigma-1}{\sigma}\left[1+n(1+t^{tl})^{1-\sigma}\right] r_d^{tl}(\varphi) \\
&= (\sigma-1)\left[1+n(1+t^{ct})^{1-\sigma}\right] f \left(\frac{1}{\varphi^{ct}}\right)^{\sigma-1} \varphi^{\sigma-1} - \\
&\quad (\sigma-1)\left[1+n(1+t^{tl})^{1-\sigma}\right] f \left(\frac{1}{\varphi^{tl}}\right)^{\sigma-1} \varphi^{\sigma-1} \\
&= (\sigma-1) f \left[\frac{1+n(1+t^{ct})^{1-\sigma}}{(\varphi^{ct})^{\sigma-1}} - \frac{1+n(1+t^{tl})^{1-\sigma}}{(\varphi^{tl})^{\sigma-1}}\right]. \qquad (4.7)
\end{aligned}$$

As shown in the appendix of Melitz (2003) since $\frac{\partial\left[\frac{1+n(1+t)^{1-\sigma}}{\varphi^{\sigma-1}}\right]}{\partial t} < 0$, the expression in square brackets is negative. Notice that $t^{ct} > t^{tl}$, $\frac{1+n(1+t^{ct})^{1-\sigma}}{(\varphi^{ct})^{\sigma-1}} < \frac{1+n(1+t^{tl})^{1-\sigma}}{(\varphi^{tl})^{\sigma-1}}$, and $l^{ct} - l^{tl} < 0$ and exporters hire workers. Once again, we see that the larger the change in tariffs, the larger its effect will be on the net labor hires for exporters. Moreover, taking the derivative of equation 4.7:

$$\frac{\partial l^{ct} - l^{tl}}{\varphi} = (\sigma-1)^2 f \left[\frac{1+n(1+t^{ct})^{1-\sigma}}{(\varphi^{ct})^{\sigma-1}} - \frac{1+n(1+t^{tl})^{1-\sigma}}{(\varphi^{tl})^{\sigma-1}}\right] \varphi^{\sigma-2} > 0, \qquad (4.8)$$

we find that if a firm is more productive it hires more workers.

Table 2: **Descriptive Statistics**

	Suffer=1				Suffer=0			
	Mean	Std. Dev.	P(25)	P(75)	Mean	Std. Dev.	P(25)	P(75)
LAID OFF WORKERS	176.908	421.875	27	184	233.519	634.406	25	200
TFP	0.999	0.007	0.996	1.002	1.000	0.008	0.997	1.003
TARIFF	0.026	0.032	0.005	0.036	0.033	0.041	0.007	0.0457
LIBER	0.002	0.007	-0.000	0.002	0.002	0.009	-0.000	0.003
SIZE	22989.91	30870.77	3411	29000	32695.65	40770.91	4800	43000
LABOR_COST	824.724	1263.445	91.636	960.085	1010.319	1441.828	138.405	1250.752
IMPORTS	3.179	2.443	1.371	4.457	2.219	2.161	0.662	3.304
POLIT	0.547	0.498	0	1	0.719	0.450	0	1
EXPORT	0.912	0.284	1	1	0.946	0.226	1	1
N	1158				905			