Men, Women, and Machines: How Trade Impacts Gender Inequality

Chinhui Juhn[a],
Gergely Ujhelyi[b]
and Carolina Villegas-Sanchez[c]

September 2013

Abstract

This paper studies the effect of trade liberalization on an under-explored aspect of wage inequality – gender inequality. We consider a model where firms differ in their productivity and workers are differentiated by skill as well as gender. A reduction in tariffs induces more productive firms to modernize their technology and enter the export market. New technologies involve computerized production processes and lower the need for physically demanding skills. As a result, the relative wage and employment of women improves in blue-collar tasks, but not in white-collar tasks. We test our model using a panel of establishment level data from Mexico exploiting tariff reductions associated with the North American Free Trade Agreement (NAFTA). Consistent with our theory we find that tariff reductions caused new firms to enter the export market, update their technology and replace male blue-collar workers with female blue-collar workers.

JEL: D3,F15,J16 .

Keywords: trade, gender, inequality.

---

[a]Corresponding author. University of Houston and NBER, Department of Economics, University of Houston, Houston, TX 77204-5882, (Tel) 713-743-3823, (Email) cjuhn@uh.edu

[b]University of Houston, Department of Economics, University of Houston, Houston, TX 77204-5882, (Tel) 713-743-3815, (Email) gujhelyi@uh.edu

[c]ESADE-Universitat Ramon Llul, Department of Economics, E-08034 Barcelona, Spain, (Tel) +34-932-806-162, (Email) carolina.villegas@esade.edu

1 Introduction

In this paper, we consider an under-explored aspect of trade liberalization – its impact on gender inequality in the labor market. It is well-known that labor market inequality can reinforce gender inequality in other areas, including education, health, or the treatment of women in the household (see Duflo (2012) for a survey). Given that many developing countries have already adopted or are now in the process of adopting trade liberalization policies, an important question is whether this will move them closer to, or further from, the goal of gender equality, one of the eight stated goals in the U.N. Millennium Development Goals Report (UN, 2009). Aside from equity concerns, the effect of liberalization policies on gender outcomes may also be of interest from a long-run growth perspective since there is now growing evidence that empowering women promotes education and better children's outcomes (Thomas (1990), Duflo (2003), Qian (2008)).

Our theory builds on the basic framework of the new trade models of Melitz (2003), Bustos (2011a), Bustos (2011b) and their predecessors. Heterogenous firms choose between old and new technologies that require different amounts of white and blue-collar tasks. White and blue collar tasks can be performed by male or female workers. Reminiscent of Autor, Levy, and Murnane (2003) in which computers replace the need for routine physical tasks, the new technology in our model replaces the need for physically demanding skills, "brawn."[1] Thus, relative to the old technology, women are more productive in blue-collar jobs in the new technology. By lowering the cost of entering foreign markets, trade liberalization causes some firms to start exporting and adopt the modern technology. This improves women's labor market outcomes in the blue-collar tasks, while leaving them unchanged in the white-collar tasks.

We test our model using establishment level data from Mexico, exploiting tariff reductions associated with the North American Free Trade Agreement (NAFTA). Consistent with the previous literature and the predictions of our model, we find that tariff reductions increased exports through the entry of new firms into the export sector. We find evidence that these newly exporting firms updated their machinery and equipment, not only relative to non-exporting firms but also relative to existing exporters. Moreover, investment was especially pronounced in the new, computerized

[1] Empirical evidence in Weinberg (2000) and Rendall (2010) on the process of technological change in the US also supports this assumption.

equipment category imported from developed countries. As predicted by our model, we find that tariff reductions improved female labor outcomes through this channel. Trade liberalization increased the ratio of female blue-collar workers to male blue-collar workers as well as the relative wage of female blue-collar workers. By contrast, we find little evidence of increasing female shares in white-collar occupations, where the relative importance of physically demanding skills is unlikely to have changed. We provide several robustness checks to make sure that these results are not due to the endogeneity of tariffs. We provide evidence that other mechanisms, including import market competition or the different attitudes towards women among foreign firms are unlikely to explain our findings.

In terms of skill distribution within firms (measured as the ratio of white-collar to blue-collar workers), we find mixed results. We find little evidence of skill-upgrading in newly exporting firms in terms of employment but we do find larger increase in white-collar wages, both in absolute terms and relative to blue-collar wages. These results are consistent with the idea that labor inputs are differentiated along multiple dimensions: gender-specific skills as well as the more traditional occupation-specific skills.

In studying the effect of trade liberalization on gender inequality, our paper brings together two distinct literatures: a trade literature on the effects of trade liberalization in developing countries, and a labor literature on skill-biased technological change. The first, more recent literature has studied the effect of trade liberalization on heterogenous firms, finding evidence for technology and quality upgrading as well as wage effects. Bustos (2011b) builds a model where firms that differ in productivity choose technology as well as export status. Using a panel of Argentinean manufacturing firms in the context of a regional free trade agreement, MERCOSUR, she finds that trade liberalization led to increases in spending on technology and hiring of more skilled workers. Verhoogen (2008) uses a similar set-up but uses exchange rate shocks, rather than tariff reductions, as source of variation. Using a panel data set of Mexican manufacturing plants, he finds that the 1994-1995 peso devaluation increased exports and wages particularly at those plants with higher initial productivity. Csillag and Koren (2011) study a period of trade liberalization in Hungary, and show that employees working with machinery imported from developed countries earn a wage premium. They argue that such machinery represents technology upgrading, which is consistent with the interpretation of our findings.[2]

The second literature is a labor literature on skill-biased technological change that has described the implications of technology upgrading for gender inequality. This literature has primarily focused on the evolution of wage inequality between men and women in the US (e.g., Blau and Kahn (1997), Weinberg (2000), Autor, Levy, and Murnane (2003), Rendall (2010)). We take from this literature the idea that technological change, in particular the introduction of computerized production processes, has lowered the need for physically demanding skills and has therefore favored women in certain occupations (see also Galor and Weil (1996)).

While the link between trade liberalization and demand for skilled workers has been widely and rigorously examined with firm and industry level data,[3] there is relatively little work exploring labor market outcomes of men and women.[4] Most previous papers use household surveys to examine trends in the gender wage gap and are different from the approach taken here. In one of the earliest studies to employ firm-level data to study gender outcomes, Ozler (2000) finds that female employment share is positively related to export share of output among manufacturing plants in Turkey. The study is based on a single cross section and does not discuss the possible channels leading to this empirical finding. Ederington, Minier, and Troske (2010) use firm level data and find that Colombian tariff reforms increased relative employment of blue-collar women, an empirical

[2] Different approaches have been taken to model how firm-level heterogeneity translates into wage inequality among workers. Departing from the assumption of perfect labor markets, Helpman, Itskhoki, and Redding (2010) and Helpman, Itskhoki, and Redding (2011) introduce search frictions where more productive firms search more intensively for quality workers and pay higher wages. Similarly, Amiti and Davis (2012) develop a model of fair wages in which more productive firms share profits and pay higher wages to workers. Trade and the entry of these productive firms into the export sector increases their revenue relative to non-exporting firms, thereby increasing wage dispersion across firms. Frias, Kaplan, and Verhoogen (2009) show that labor market imperfections are empirically important in explaining the higher wages paid by exporting firms.

[3] Some earlier studies in the Mexican context include Cragg and Epelbaum (1996), Revenga (1997), Hanson and Harrison (1999), Behrman, Birdsall, and Székely (2000), Feliciano (2001), Robertson (2004). See also Pavcnik (2003), Attanasio, Goldberg, and Pavcnik (2004), Topalova and Khandelwal (2011) and Goldberg and Pavcnik (2007).

[4] Saure and Zoabi (2011) study the impact of NAFTA on the US labor market. They find that trade liberalization led to lower female labor force participation and increased the gender wage gap in the US. This forms an interesting contrast to our findings on the other side of the border, and suggests that the impact of trade liberalization on gender outcomes may depend on the level of economic development. Oostendorp (2009) provides a cross-country study of globalization and gender outcomes.

finding they interpret as being due to reductions in discrimination. Aguayo, Airola, Juhn, and Villegas-Sanchez (2013) use household and firm level data and find tariff changes accompanying NAFTA increased demand for female labor within and between industries. Relative to this previous paper, we offer a more in-depth analysis of the mechanisms underlying the within-industry increase in female employment and wage bill share.[5]

More broadly, our paper contributes to the literature on the determinants of gender roles during the process of economic development (see, e.g., Alesina, Giuliano, and Nunn (2011) or the survey by Duflo (2012)). Our results suggest that the opening up of trade may have important consequences for the status of women in society.

This paper is organized as follows. Section 2 summarizes the tariff reductions that accompanied signing of NAFTA in 1994, describes the basic trends in relative wages and employment of women in Mexico over the 1990s and motivates the link between trade and gender that we formally developed in the model of Section 3. Section 3 outlines the model which links trade liberalization and the demand for female labor. Section 4 describes the data. Section 5 presents the main empirical results. Section 6 concludes.

2 Background

We study a particular trade liberalization episode during the 1990s, the case of Mexico. Mexico implemented unilateral tariff reductions in the 1980s to join the GATT in 1986. By 1987, the highest tariff was reduced to 20% and the tariff structure was simplified to include only 5 different rates: 0%, 5%, 10%, 15%, 20%. Starting in 1990, Mexico's opening strategy switched to pursuing bilateral free trade agreements, with the most important being the North American Free Trade Agreement (NAFTA) with U.S. and Canada which took effect in 1994. On average, tariffs applied by US (export tariffs) in 1991 were 6.1 percent and fell between 1991 and 2000 by approximately 5 percentage points. The data is based on the CMAP industry classification and there is considerable variation in the size of the declines across industries. Meanwhile, during the same period, Mexican tariffs imposed on imports from NAFTA countries (import tariffs) decreased on average by 13

[5]See Juhn, Ujhelyi, and Villegas-Sanchez (2013) for a summary of some of our results.

percentage points (from 16.1 percent in 1991 to 2.6 percent in 2000) across CMAP sectors.[6] Since more than 80% of the trade occurs with the U.S., we would expect a priori that the decline in tariffs would lead to large increases in trade flows. Figure 1 shows the trends in exports and imports as fractions of GDP. The figure shows that while the unilateral tariff reductions had some impact in the 1980s, trade flows accelerated in the 1990s, after the bilateral agreement with the major trading partner was reached. Interestingly, trade flows appear to have stagnated again in the 2000s most likely due to a recession in the U.S. and China's entry into the WTO.

2.1 Trends in Women's Relative Wage and Employment Share

While the focus of this paper is to study the impact of trade on production within the firm, it is nevertheless useful to start with an overview of the aggregate change in female wages and employment over this period. Aguayo, Airola, Juhn, and Villegas-Sanchez (2013) use household surveys to examine economy-wide changes. They conclude that women's relative wage increased slightly even as their relative employment rates increased, suggesting that demand for female labor in the economy as a whole increased.[7] They find that a significant fraction (40 percent) of the increase in total wage bill share of women can be attributed to shifts in relative size of sectors (measured by employment or wage bill), a phenomenon which was spurred by the rapid decline of the agricultural sector. While labor allocation across sectors played a role, even a larger fraction of the increase in female wage bill share was due to within-industry shifts towards female labor, a phenomenon which we focus on here. Table C2 in the on-line appendix presents decompositions of the total change in female wage bill share into "between"and "within" industry shifts in employment and wage bill share. In all cases, the "within" industry shift towards female labor accounts for a large portion of the total change. Below, we investigate the link between trade liberalization and this type of within-industry and within-firm shifts towards female labor.

[6] We thank Leonardo Iacovone for providing us with the tariff data. Tariff data was available originally at the 8-digit Harmonized System (HS) classification and was matched to the Mexican CMAP class classification as explained in Iacovone and Javorcik (2010). More information on the tariff data is provided in the on-line appendix Table C1.

[7] Aguayo, Airola, Juhn, and Villegas-Sanchez (2013) findings are based on Household Income and Expenditure Surveys (ENIGH) and the 1990 and 2000 Mexican Population Census. The wage sample consists of men and women who are 15-64 years old, who reported working full-time (30 hours or more), and who either did not have self-employment earnings or reported that they were not self-employed.

2.2 Trade Liberalization and Gender

Why would trade liberalization have a differential impact on female labor within industries and firms? One possible channel is through the reduction of discrimination brought about by foreign competition, along the lines of Becker (1957). Testing this theory, Black and Brainerd (2004) find that US industries which were subject to more competition through trade liberalization experienced greater reductions in the gender wage gap. A recent paper by Ederington, Minier, and Troske (2010) finds similar results for employment in Colombia, where plants operating in industries subject to greater tariff reductions increased the hiring of female blue-collar workers relative to male blue-collar workers. The discrimination story begins with the assumption that men and women are equally productive in the production process. Another possibility, which we explore here, is that men and women embody different amounts and types of skills, and in particular, women have lower amounts of physical skill, "brawn," relative to men. Trade liberalization induces firms to acquire new technology that complements female labor by reducing the need for physical skills. Some of these ideas are explored in Weinberg (2000) who uses U.S. data and shows that female employment growth is positively related to computer-use across industries and occupations.

To get a sense of how employers view female and male workers, we examined questions on hiring preferences which were asked of employers in our balanced panel of firms.[8] In the survey, employers were asked whether they had a preference for hiring males or females or whether they were indifferent between the two. Panel A of Table 1 summarizes the responses to this question by occupation category. The panel shows that there are large differences for male preference across occupation categories, with the most pronounced male preference being in blue-collar occupations such as "specialized workers" and "general workers." For white collar workers such as "managers" employers exhibit no particular preference for hiring male workers. The absence of male preference in white collar work suggests that simple taste discrimination, where men are preferred irrespective of the tasks that need to be performed, cannot be the major driving force. In a follow-up question employers are asked the reasons for their preferences and these answers are reported in Panel B of Table 1. For blue-collar occupations, "heavy work" is overwhelmingly the most common reason given for male preference. Table 1 gives credence to the notion that employers view men and women

[8]See Section 4 for a full description of the ENESTyC survey and the data.

as distinct inputs with different amounts of skills, particularly when it comes to physical skills in blue-collar occupations.

3 The Model

The foregoing patterns, showing how employer preferences for male workers differ by task, motivate our theory which is based on the idea that workers embody different gender-specific skills. The model yields predictions of worker outcomes differentiated by gender and occupation. The model also lays out the mechanism which links tariff reductions and gender-specific outcomes providing testable implications - such as the impact of tariff reductions on exports and technology - which we bring to the data. We set up the model, derive the equilibrium, and then present the predictions that are tested in the empirical section below.

3.1 Setup

Our setup follows closely the extension of the Melitz (2003) model proposed by Bustos (2011a, 2011b). While Bustos considers workers who are differentiated by skills along one dimension (low vs. high), we allow workers to be differentiated by both gender-specific and occupation-specific skills.

An economy has consumers with CES preferences buying a continuum of differentiated products. Consumer utility is $\left[\int (q_\omega)^\rho d\omega\right]^{\frac{1}{\rho}}$ where q_ω is consumption of product variety ω. Under prices p_ω, demand for variety ω is $q_\omega = EP^{\sigma-1}p_\omega^{-\sigma}$, where $\sigma = \frac{1}{1-\rho}$, E is total spending and P is the price index. Each product variety is produced by a single firm. Firms decide whether to enter the market at some fixed cost f_e. If they enter, they observe their productivity φ, a random draw from a Pareto distribution $G(\varphi) = 1 - \varphi^{-k}$ on $[1, \infty)$. Once productivity is realized, firms can exit. If they stay, they can choose between two technologies, 1 and 2. Technology 1 is a "traditional" technology involving relatively more physically demanding blue collar tasks (such as operating heavy machinery). Technology 2 is a "modern" technology that involves computerized production processes, and achieves higher total factor productivity. Labor is differentiated by both occupation (blue or white collar) and gender. White collar workers and female blue collar workers have relatively higher productivity under technology 2. This is based on empirical evidence in Bustos (2011b), showing that exporting firms choose technologies that use more educated workers, and in Weinberg (2000), showing that modern computerized production technologies favor female workers.[9]

To capture these features, we assume that production involves a combination of blue collar (Y_b) and white collar (Y_w) intermediate inputs (or tasks) according to a Cobb Douglas production function

$$Q_t(Y_b, Y_w) = A_t(\varphi) Y_b^{\alpha_t} Y_w^{1-\alpha_t}$$

for each technology $t = 1, 2$. For simplicity, $A_1(\varphi) = \varphi$ and $A_2(\varphi) = \gamma\varphi$, where $\gamma > 1$ to capture higher total factor productivity under the modern technology. We let $\alpha_1 > \alpha_2$, capturing the importance of white collar tasks under the modern technology. We further let intermediate inputs be produced using female (f) and male (m) labor with the appropriate skills (blue or white collar):

$$\begin{aligned} Y_b(L_{bf}, L_{bm}, t) &= (L_{bf})^{\beta_t}(L_{bm})^{1-\beta_t} \\ Y_w(L_{wf}, L_{wm}, t) &= (L_{wf})^{\varpi_t}(L_{wm})^{1-\varpi_t} \end{aligned}$$

for $t = 1, 2$. We assume $\beta_1 < \beta_2$ to capture the higher productivity of female workers in the blue collar category with technology 2. Technology 1 has a fixed cost f_1 and technology 2 a higher fixed cost $f_2 > f_1$. Firms take factor prices $W = (W_{bf}, W_{bm}, W_{wf}, W_{wm})$ and the price index P of the consumption goods as given.

Firms that remain on the market also choose whether to export (x) or serve only the domestic market (d). The export market is characterized by the same demand structure as the domestic market.[10] Exporting has a fixed cost f_x and iceberg trade costs denoted τ. Given the technology

[9] See also Autor, Levy, and Murnane (2003) and Rendall (2010).

[10] One could allow domestic and foreign consumers to have different willingness to pay, as in Verhoogen (2008). Similarly, skill intensity in exporting firms could differ depending on the export market destination. Brambilla, Lederman, and Porto (2012) find that firms that export to high-income destinations hire more skills and pay higher wages than firms that export to middle-income countries or that sell domestically. We assume away such destination-market effects to keep the model simple. In addition, our empirical investigation makes use of Mexican manufacturing data. US is the main destination market for Mexican exporters accounting for over 80 percent of total exports. Therefore, our dataset is ill-suited to study heterogenous effects across export market destinations.

each firm maximizes its profit by choosing the price p_ω^d of its product on the domestic market (as well as a price p_ω^x if exporting) subject to consumer demand and the factor prices.

3.2 Equilibrium

Let δ be an indicator variable equal to 1 if a firm exports and 0 otherwise. Given the technology choice ($t = 1, 2$) and the export decision, a firm's factor demand is $L_j^t(W, P, \varphi, \delta)$ for each type j of the labor input ($j = bf, bm, wf, wm$). These factor demands can be obtained using Shepard's lemma and the firm's total cost function.[11] The relative demand for female vs. male workers within each occupational category of a firm using technology t is

$$\frac{L_{bf}^t}{L_{bm}^t} = \frac{\partial TC_t/\partial W_{bf}}{\partial TC_t/\partial W_{bm}} = \frac{\beta_t}{1-\beta_t}\frac{W_{bm}}{W_{bf}} \quad (1)$$

$$\frac{L_{wf}^t}{L_{wm}^t} = \frac{\partial TC_t/\partial W_{wf}}{\partial TC_t/\partial W_{wm}} = \frac{\varpi_t}{1-\varpi_t}\frac{W_{wm}}{W_{wf}}. \quad (2)$$

Once the technology choice and the decision on exporting have been made, let $\pi_t(W, P, \varphi, \delta)$ denote a firm's maximized profit.[12] Comparing these profits, a firm with productivity φ decides whether to stay on the market and whether to export. Specifically, there is a productivity cutoff $\varphi_1^*(W, P)$ above which firms stay in the market (i.e., serve at least the domestic market), a cutoff $\varphi_x^*(W, P)$ above which firms start exporting, and a cutoff $\varphi_2^*(W, P)$ above which they adopt technology 2. Given W and P, these cutoffs determine total factor demand in the economy. For

[11] For technology t, this is

$$TC_t(q, W, P, \varphi, \delta) = Pf_t + \delta Pf_x + \frac{q^d + \delta\tau q^x}{A_t(\varphi)\kappa_t} W_{bf}^{\alpha_t\beta_t} W_{bm}^{\alpha_t(1-\beta_t)} W_{wf}^{(1-\alpha_t)\varpi_t} W_{wm}^{(1-\alpha_t)(1-\varpi_t)},$$

where q^d and q^x denote sales on the domestic and export markets, and $\kappa_t = (\alpha_t\beta_t)^{\alpha_t\beta_t}(\alpha_t(1-\beta_t))^{\alpha_t(1-\beta_t)}((1-\alpha_t)\varpi_t)^{(1-\alpha_t)\varpi_t}((1-\alpha_t)(1-\varpi_t))^{(1-\alpha_t)(1-\varpi_t)}$. This expression for the total costs assumes that prices are the same in the domestic and export markets, which will be true in equilibrium.

[12] Solving the firm's problem, this can be obtained as

$$\pi_t(W, P, \varphi, \delta) = (1 + \delta\tau^{1-\sigma}) r_t(W, P, \varphi)/\sigma - Pf_t - \delta Pf_x$$

where $r_t(W, P, \varphi) = E(P\rho)^{\sigma-1}[W_{bf}^{\alpha_t\beta_t} W_{bm}^{\alpha_t(1-\beta_t)} W_{wf}^{(1-\alpha_t)\varpi_t} W_{wm}^{(1-\alpha_t)(1-\varpi_t)}]^{1-\sigma}(A_t(\varphi)\kappa_t)^{\sigma-1}$ is the revenue of a firm that does not export.

example, if $\varphi_1^* < \varphi_x^* < \varphi_2^*$, then total demand for type j labor is

$$L_j^1 + L_j^2 = \int_{\varphi_1^*}^{\varphi_x^*} L_j^1(W,P,\varphi,\delta=0)dG(\varphi) + \int_{\varphi_x^*}^{\varphi_2^*} L_j^1(W,P,\varphi,\delta=1)dG(\varphi) + \int_{\varphi_2^*}^{\infty} L_j^2(W,P,\varphi,\delta=1)dG(\varphi).$$

This can be easily computed using the Pareto distribution assumption and the factor demands from the firm's profit maximization problem. It will be convenient to work with ratios rather than levels, and we find

$$\frac{L_{bf}^1}{L_{bf}^2} = \frac{\alpha_1\beta_1}{\alpha_2\beta_2}\frac{R_1}{R_2} \tag{3}$$

$$\frac{L_{bm}^1}{L_{bm}^2} = \frac{\alpha_1(1-\beta_1)}{\alpha_2(1-\beta_2)}\frac{R_1}{R_2} \tag{4}$$

$$\frac{L_{wf}^1}{L_{wf}^2} = \frac{(1-\alpha_1)\varpi_1}{(1-\alpha_2)\varpi_2}\frac{R_1}{R_2} \tag{5}$$

$$\frac{L_{wm}^1}{L_{wm}^2} = \frac{(1-\alpha_1)(1-\varpi_1)}{(1-\alpha_2)(1-\varpi_2)}\frac{R_1}{R_2}, \tag{6}$$

where R_t is the aggregate revenue of firms using technology t (which is a function of the wages W, the productivity cutoffs and the price index P).

Equilibrium on the labor market requires aggregate demand for each type j labor to equal its supply, assumed constant at $\bar{L}_j$. This defines the wages W as a function of the productivity cutoffs and the price index P. Using the decomposition $\frac{L_j^1+L_j^2}{L_{j'}^1+L_{j'}^2} = \frac{L_j^2}{L_{j'}^2}\frac{1}{L_{j'}^1/L_{j'}^2+1} + \frac{L_j^1}{L_{j'}^1}(1-\frac{1}{L_{j'}^1/L_{j'}^2+1})$, together with (1)-(2) and (3)-(6), the equilibrium conditions for the relative wages can be written as

$$\frac{\bar{L}_{bf}}{\bar{L}_{bm}} = \frac{W_{bm}}{W_{bf}}\left[\frac{\beta_1}{1-\beta_1} + \left(\frac{\beta_2}{1-\beta_2} - \frac{\beta_1}{1-\beta_1}\right)\frac{1}{1+\frac{\alpha_1(1-\beta_1)}{\alpha_2(1-\beta_2)}\frac{R_1}{R_2}}\right] \tag{7}$$

$$\frac{\bar{L}_{bf}}{\bar{L}_{wf}} = \frac{W_{wf}}{W_{bf}}\left[\frac{\alpha_1\beta_1}{(1-\alpha_1)\varpi_1} + \left(\frac{\alpha_2\beta_2}{(1-\alpha_2)\varpi_2} - \frac{\alpha_1\beta_1}{(1-\alpha_1)\varpi_1}\right)\frac{1}{1+\frac{(1-\alpha_1)\varpi_1}{(1-\alpha_2)\varpi_2}\frac{R_1}{R_2}}\right] \tag{8}$$

$$\frac{\bar{L}_{wf}}{\bar{L}_{wm}} = \frac{W_{wm}}{W_{wf}}\left[\frac{\varpi_1}{1-\varpi_1} + \left(\frac{\varpi_2}{1-\varpi_2} - \frac{\varpi_1}{1-\varpi_1}\right)\frac{1}{1+\frac{(1-\alpha_1)(1-\varpi_1)}{(1-\alpha_2)(1-\varpi_2)}\frac{R_1}{R_2}}\right] \tag{9}$$

The model is closed by assuming free entry. In particular, before learning their productivity φ, firms must be indifferent between entering the market or not. This requires expected profits (given W, P and the productivity cutoffs) to equal the fixed cost f_e of entry. Using the equations defining the productivity cutoffs, the labor market equilibrium conditions and the free entry condition, the equilibrium factor prices, price index and productivity cutoffs can be obtained.

In equilibrium, $\varphi_1^* < \varphi_2^*$: low productivity firms use the traditional technology 1 while high productivity firms are willing to pay the higher fixed cost and use technology 2. Following Bustos (2011a), we focus on the case where the export cutoff φ_x^* is between φ_1^* and φ_2^*. Thus, in equilibrium, some but not all exporting firms use the modern technology.

3.3 Trade liberalization

Trade liberalization can be modeled as a reduction in the trade costs τ. We obtain the following.

Proposition 1. *A reduction in the tariff τ (i) lowers the export cutoff φ_x^*, (ii) lowers the technology adoption cutoff φ_2^*, (iii) increases women's relative wage in the blue collar category, (iv) leads to an increase in the relative number of female workers in the blue-collar category among firms that switch to the modern technology.*

Trade liberalization makes exporting more attractive, which lowers the export cutoff φ_x^*. Since the modern technology with higher TFP is more efficient for producing the increased quantity for the export market, more firms adopt this technology (the cutoff φ_2^* decreases). Because blue collar female workers are more productive under the modern technology, firms switching technology hire more of these workers, and their relative wage $\frac{W_{bf}}{W_{bm}}$ rises.

As mentioned above, the literature strongly suggests that technology upgrading that involves switching to computerized machinery in blue collar production processes should benefit women. By contrast, there does not seem to be any a priori reason why women should have higher or lower productivity in white collar tasks under either technology. In fact, Table 1 showed that employers did not express any gender preferences in hiring for "managers," by far the largest category of white-collar workers, suggesting that employers view men and women as similar type of workers in these tasks. Assuming that this is the case, we have the following result.

Proposition 2. *If $\varpi_1 = \varpi_2 = \varpi$, then a reduction in the tariff τ (i) has no impact on women's relative wage or employment in the white collar category, (ii) raises the relative wage of white to* *blue collar workers if and only if*

$$\frac{1}{\varpi}\left(\frac{\alpha_2\beta_2}{1-\alpha_2}-\frac{\alpha_1\beta_1}{1-\alpha_1}\right)\frac{1-\alpha_1}{1-\alpha_2}-\left(\frac{\beta_2}{1-\beta_2}-\frac{\beta_1}{1-\beta_1}\right)\frac{\alpha_1(1-\beta_1)}{\alpha_2(1-\beta_2)}\frac{(1+\frac{(1-\alpha_1)}{(1-\alpha_2)})^2}{(1+\frac{\alpha_1(1-\beta_1)}{\alpha_2(1-\beta_2)})^2}\frac{\frac{W_{bf}}{W_{wf}}}{\frac{\beta_t}{1-\beta_t}+\frac{W_{bf}}{W_{bm}}}<0.$$

Part (i) of the proposition states that when technology choice does not affect gender differences in white collar tasks, trade liberalization does not affect women's relative outcomes in this category. In addition, part (ii) offers a contrast to some of the previous literature examining trade and skill upgrading. When labor inputs are multidimensional (e.g., differentiated by gender as well as occupation-specific skills), predictions on the changes in aggregate categories, such as the wage of all skilled workers, will tend to be theoretically ambiguous. The proposition shows that even if white collar tasks are relatively more important under the new technology ($\alpha_1 > \alpha_2$), whether total wages paid in this category rise or fall depends on the parameters of the model and the pre-existing relative wages of the various inputs. Thus, the impact of trade liberalization on white to blue collar wages is an empirical matter.

4 Data

The data used in this study come from the Encuesta Nacional de Empleo, Salarios, Tecnologia y Capacitacion (ENESTyC) [National Survey of Employment, Wages, Technology and Training], which is a survey carried out by the Mexican National Statistical Office (INEGI). The analysis focuses on two waves of the survey, implemented in 1992 and 2001, which were designed as independent cross-sections. The questions in the survey refer mainly to the year prior to the implementation of the survey (i.e., 1991 and 2000).

The ENESTyC survey was designed to be representative at the sectoral level within the manufacturing sector and it is possible to identify the sector in which firms operate at a very disaggregated level. There are 52 ramas (branches) of activity and around 200 clases (classes).[13] Originally, the surveys not only included medium and large firms but also micro and small establishments.

[13] The industrial classification is based on the Clasificacion Mexicana de Actividades y Productos (CMAP) [Mexican Classification of Activities and Products]. Industries are grouped in 6-digit industries called clases (classes), 4-digit industries called ramas (branches), and 2-digit industries called divisiones (divisions).

According to the INEGI classification micro establishments are those with less than 16 employees; small establishments have between 16 and 100 employees; medium establishments are those that have between 100 and 250 employees and finally, large establishments report more than 250 employees.[14] However, in order to study the within firm effects of trade liberalization we create a balanced panel of firms between 1991 and 2000. Although the surveys were designed as independent cross-sections it is possible to link a subsample of firms over time, and we linked a total number of 938 firms between 1991 and 2000. Since the sample design of the ENESTyC surveys guarantees that medium and large firms are included with certainty, the average firm size (in terms of both sales and employment) is larger in the balanced panel (see Table C3 in the on-line appendix).

Most importantly for our study firms provide information about sales, employment, raw materials, capital, as well as their ownership structure.[15] In addition, firms report detailed information on export revenue, technology upgrading and female composition of the work force. In particular, firms report the share of export sales in total sales which allows us to determine the export status of firms in 2000 relative to their position in 1991 before the NAFTA agreement took place. Continuing exporters are firms that exported both in 1991 and 2000. New exporters are firms that did not export in 1991 but are exporting in 2000. Stop exporters are firms that exported in 1991 but do not export in 2000 and finally, non-exporters are firms that never exported during our sample period. Table C3 in the on-line appendix shows that 34 percent of the firms in 2000 are continuing exporters and 24 percent are new exporters. Similar to previous studies in the literature (see Bernard and Jensen (1999)) we find that exporters are larger both in terms of employment and sales and are also more capital intensive (see Table C4 in the on-line appendix). Interestingly we find significant differences between continuing exporters, new exporters and non-exporting firms. Continuing exporters are on average initially more productive (measured as value added per capita), employ a higher share of skilled labor, pay higher wages and pay higher wages to white collar workers relative to non-exporting firms. This is not the case for newly exporting firms. However, newly exporting firms do show a significant increase in wages and white collar wages between 1991 and 2000.[16]

[14]The survey is conducted at the establishment level. However, through out the analysis the words establishment, firm and plant will be used interchangeably.

[15]See the on-line appendix for a detailed description of the data and cleaning procedure and Table C3 in the on-line appendix for summary statistics of the variables used in the analysis.

[16]Overall, the change in female to male ratio in employment and wages among white collar workers between 1991

We are interested in exploring the relationship between export status and technology upgrading. In order to do so we use measures of investment in technology provided by the ENESTyC survey. In particular, we use the log change in the value of machinery and equipment between 1991 and 2000. In addition, we make use of several characteristics of the machinery and equipment acquired that are detailed in the 2001 survey. In this survey firms are asked to provide information on the following aspects: whether the machinery and equipment acquired was computerized or automatic (as opposed to manual or involving machinery tools), 61 percent of the firms; whether the machinery and equipment bought is new (as opposed to used), 69 percent of the firms and finally; whether the machinery and equipment was imported from developed countries, 53 percent of the firms. Overall, 35 percent of the firms in our sample bought new computerized machinery imported from developed countries.

Finally, a main feature of the ENESTyC survey is that it provides detailed information about labor outcomes disaggregated by gender and occupational category. The survey asks firms to report the number of employees and the wage bill according to four occupational categories: Directors, Managers, Specialized Workers and General Workers.[17] In addition, firms are asked to detail within each occupational category the number of female/male employees as well as the corresponding wage bill.

---

and 2000 was larger than the change among blue collar workers (see Table C3 in the on-line appendix). However, as our results in the next section show, these changes in the white collar category do not seem to be linked to the trade liberalization process.

[17]Directors are "employees that make decisions related to activities in the areas of planning, direction, production policy, financing, marketing, internal organization." Managers include "employees that are not directly involved in the production process but apply scientific knowledge and methods in a variety of areas like technology, economics, sociology, industrial, and government related areas"; professionals (lawyers, chemists, engineers, accountants, etc.; technicians (lab employees, quality control technician, hydraulic technician, electronic technician, etc.); clerical employees; and supervisors (intermediate managers in the production process who "link higher end managers with those employees in the production process floor."

5 Empirical Results

5.1 Tariffs, Export Status, and Technology

We start by documenting the relationship between trade liberalization and export status. According to Proposition 1, a reduction in trade costs lowers the export cutoff and induces firms at the margin to become exporters. To test this implication using our data, we estimate the following equation:

$$NewExporter_{i,s,2000} = \beta_{\tau}\Delta ExportTariff_s + \beta_x X_{i,s,1991} + \delta_{s'} + \Delta\epsilon_{i,s,t} \tag{10}$$

where i denotes firm and s refers to six-digit sector classification. $NewExporter_{i,s,2000}$ is a dummy variable that is equal to 1 for firms that did not export in 1991 but exported in 2000, and is equal to 0 for all other firms. $\Delta ExportTariff_s$ is the sectoral change in US tariffs from 1991 to 2000. $X_{i,s,1991}$ includes a set of initial firm characteristics that aim to control for firm size, capital intensity, R&D intensity and foreign ownership. $\delta_{s'}$ are two-digit sector fixed effects. Based on the implications of the model we expect β_{τ} to be negative and significant so that the probability of being a newly exporting firm is highest in industries that witnessed the largest declines in US tariffs.

Columns (1) and (2) in Table 2 show the results from estimating equation (10). Notice that we cluster standard errors at the cmap level to avoid any potential biases resulting from estimating the effect of an aggregate variable (tariff changes correspond to cmap level classification) on firm level outcomes. As expected, the probability of being a newly exporting firm is highest in those industries where the reduction in US tariffs is largest. In particular, our point estimate of -0.042 implies that a firm in an industry experiencing the average reduction in US tariffs (5.2 percentage points) is 21 percentage points more likely to be a newly exporting firm relative to firms that experienced zero tariff change. These results suggest that the impact of tariffs on the extensive margin, the entry of firms into the export market, plays an important role.[18]

We next explore the relationship between tariff changes and the intensive margin by regressing firm-level change in export revenue (as a share of total sales) on tariff changes. Our sample consists

[18] In columns (1) and (2) the control group are continuing exporters, non-exporters and stop-exporters. However, similar results (coefficient -0.046(std. error 0.006)) are obtained if we focus on the sample of firms that were not exporting in 1991 (i.e., we directly compare newly exporters to non-exporters).

of firms who exported in 2000 (i.e., both firms that enter the export market and firms that were already exporting in 1991 and continue exporting in 2000).[19] Columns (3) and (4) in Table 2 report the results. While the coefficients are negative in sign, we do not find a significant relationship between within-firm increase in exports and changes in US tariffs.

An important mechanism linking trade to worker outcomes in our model is the adoption of new technology. According to Proposition 1, a reduction in trade costs lowers the cutoff for technology adoption among exporting firms and more firms will switch to the new technology. Should these effects appear primarily among continuing exporters or among firms that newly enter the export market? Depending on the position of the technology adoption and export cutoffs before and after the policy change, technology adoption may be more extensive among newly exporting firms or among continuing exporters. As illustrated on Figure 2, if the export cutoff φ_x^* and the technology adoption cutoff φ_2^* are close to each-other and move together as the tariffs decline, almost all new exporters adopt technology 2 while most continuing exporters do not change their technology. In other cases, technology adoption may be more extensive among the continuing exporters. In order to investigate this issue, we estimate the following equation:

$$\begin{aligned} \Delta Technology_{i,s'} &= \beta_1 ContinuingExporters_{i,s',2000} + \beta_2 NewExporters_{i,s',2000} \\ &\quad + \beta_3 StopExporters_{i,s',2000} + \beta_x X_{i,1991} + \delta_{s'} + \epsilon_{i,s',2000}, \end{aligned} \tag{11}$$

where "ContinuingExporters" refers to firms who exported in both 1991 and 2000, "NewExporters" refers to firms who did not export in 1991 but exported in 2000, "StopExporters" refers to firms who stopped exporting, and the omitted category is "Non-Exporters," who did not export in both years. The rest of the RHS variables are the same as in equation (10). "ΔTechnology" refers to the log change in the value of machinery and equipment between 1991 and 2000.[20] We refine this variable further by exploiting information in the 2001 survey regarding the type of technology purchased by the firm. In particular, our model considers technology upgrading towards less "brawn" intensive skills. One of the advantages of the ENESTyC survey is that it includes questions on the type of machinery and equipment introduced. We can therefore attempt to

[19]Similar results are obtained if we only focus on the sample of continuing exporters.

[20]Similar qualitative results although slightly weaker were obtained when we use log change in the value of machinery and equipment as share of total assets. Notice firm size is already accounted for by the additional control variables included in equation (11).

distinguish the mere acquisition of machinery from the type of technology upgrading in our model. In particular, we consider technology to be upgraded if the machinery and equipment acquired since 1999 is automatic/computerized (as opposed to manual or involving machinery tools), if it is new machinery (as opposed to used machinery), and if it is imported from developed countries.

Table 3 shows the results from estimating equation (11). Columns (1) and (2) show that new exporters are more likely to have undertaken large investment projects in machinery and equipment during 1991 to 2000 compared to non-exporters. In Columns (3)-(4) and (5)-(6), we separate the acquisition of machinery according to whether it involves technology upgrading as defined above. In Columns (3) and (4), the dependent variable is the product of the log difference in the value of machinery and equipment between 2000 and 1991 and a dummy variable that equals one if the firm upgraded its technology. The dependent variable in Columns (5) and (6) is defined similarly for *non-upgraded* technology. The results confirm that the difference between exporters and non-exporters comes from technology upgrading, as opposed to the mere purchase of machinery. While in Columns (5) and (6) there are no significant differences between exporters and non-exporters regarding non-upgraded machinery and equipment, Columns (3) and (4) show a very different picture with respect to upgraded machinery. In particular, the results show that exporting firms, both new and continuing exporters, are likely to upgrade their technology towards modern, less "brawn" intensive machinery and equipment compared to non-exporting firms.

Finally, we test the main implication of our model regarding technology adoption: tariff reductions induce firms to invest in the new technology. We estimate the following equation:

$$\Delta Technology_{i,s'} = \beta_\tau \Delta ExportTariff_s + \beta_x X_{i,s,1991} + \delta_{s'} + \Delta\epsilon_{i,s,t} \qquad (12)$$

Results are reported in Table 4. Consistent with the predictions of our model, columns (3) and (4) show that changes in value of upgraded machinery and equipment are strongly positively related to tariff reductions at the sectoral level.

As mentioned in the introduction, some previous studies find evidence that exporting firms employ more educated workers. While skill-upgrading is not our main focus, because we expect to find higher education levels in white collar tasks, our theory does speak to this question as well. As Proposition 2(ii) suggests, when workers are differentiated by gender (gender-specific skills) as well as occupation-specific skills, we may find different results on the effect of trade liberalization when focusing on only these dimensions. We study this in the on-line appendix (see Table B1), and find little evidence of skill-upgrading in newly exporting firms in terms of employment but we do find larger increase in white-collar wages, both in absolute terms and relative to blue-collar wages. These results are consistent with our model of multi-dimensional labor inputs.

5.2 Tariffs and Gender Labor Outcomes

We now turn to our main empirical results on gender outcomes. A key implication of our model is that trade liberalization increases the number of new exporting firms and these firms adopt a new technology that increases the productivity of female workers in blue-collar tasks. Accordingly we should observe an increase in the relative wage of female workers in the blue collar category (Proposition 1(iii)). Similarly, we should observe larger increases in relative employment of female workers in blue collar tasks associated with tariff reductions (Proposition 1(iv)). By contrast if, as seems plausible, the new technology did not enhance the relative productivity of women in white-collar tasks, we expect no effect on women's relative outcomes in this category (Proposition 2(i)).

To test these predictions, we estimate the following equation:

$$\Delta FemaleRatio_{i,s} = \beta_\tau \Delta ExportTariff_s + \beta_x X_{i,s,1991} + \delta_{s'} + \Delta\epsilon_{i,s} \qquad (13)$$

where i denotes firm and s refers to sector. $\Delta FemaleRatio_{i,s}$ refers to log change in the ratio of female to male outcomes for the three variables– employment, wage bill, and wage. Employment is the monthly number of workers reported by the firm. Wage bill is the real monthly expenditure spent on workers by the firm (pesos of 2003 using CPI data from Banco de Mexico). We obtain average monthly wage of a worker by dividing the monthly wage bill by employment.[21] As before $X_{i,s,1991}$ include a set of initial firm characteristics.

Columns (1) to (3) of Table 5 refer to white-collar occupations while columns (4) to (6) refer

[21] As a sensitivity analysis we repeated the exercise using winsorized values of these female to male ratios at 1 and 99 percent as well as 2.5 and 97.5 percent of the distribution and all our main findings go through. Similarly, results are robust to dropping observations with lower/higher values than the 1 and 99 percentile or 2.5 and 97.5 percentile of the distribution.

to blue-collar occupations.[22] As shown in the first three columns, we find no evidence that tariff reductions improved relative outcomes of women in white-collar occupations in terms of all three variables, employment share, wage bill share, and wage. By contrast, we find that reductions in tariffs are associated with larger increases in the growth of female employment and wage bill shares for blue-collar workers. For example, the coefficient -0.040 suggests that a firm in an industry experiencing the average reduction in US tariffs of 5.2 percentage points increased female employment share in blue-collar occupations by approximately 20 percent more than a firm experiencing zero tariff change. In terms of wage bill share, the effects are even larger, with the average tariff reduction causing a 24 percent larger increase in women's relative wage bill share.

In columns (7)-(9) we stack the firm-level information on blue and white workers and formally test for differential impact of tariffs across categories. We present results of the fully interacted model where all controls are interacted with the blue-collar dummy. The difference between white and blue-collar is significant at the 5 percent level for employment shares, and at the 10 percent level for wage bill shares. There is no statistically significant difference in terms of relative wage ratios, even though the reduction for blue collar wages is statistically significant, while for white collar wages it is not.

These results strongly support our model: we find improving female outcomes exactly in the employment category where we expect the relative importance of "brawn" to decline as a result of improved technology.

5.3 Potential Threats to Identification

One potential concern is endogeneity of tariff changes across industries. It is possible, for example, that industries with larger firms were able to lobby for more protection, or alternatively, tariff changes were concentrated in industries with more productive firms which were deemed to be more internationally competitive. Such omitted industry characteristics may in turn be correlated with changes in relative female outcomes.

[22]Notice that the number of observations in the columns that refer to wage equations (columns (3) and especially (6)) are lower than the corresponding columns for employment and wage bill. The variable wage is defined as the ratio of wage bill to employment. If the company reports zero or missing female employment in a particular occupational category the wage cannot be computed.

There are features of the NAFTA agreement which make it unlikely that firms or industries were able to lobby the U.S. and Mexican governments for differential treatment. NAFTA was a comprehensive trade agreement which sought to eliminate tariffs on both sides in a relatively short period. NAFTA reduced tariff rates with the U.S. from a maximum of 20% to zero in 15 years and many of the reductions to zero took immediate effect (Zabludovsky (2005)). Figure 3 graphs the 1991-2000 change in export tariffs (U.S. tariffs) at the industry-level on initial tariffs in 1991. The figure demonstrates the comprehensive nature of the reform with tariff declines equaling pre-reform tariff levels for most industries and allaying the concern that discretionary timing of tariff changes due to differential lobbying efforts are driving our results.[23]

Of course, initial tariff levels themselves could potentially be endogenous. It may be the case that past levels of trade protection are related to omitted industry characteristics which, in turn, are related to future industry performance. To address this concern, we examine whether initial (U.S.) tariff levels are correlated with past (Mexican) industry characteristics such as log employment, log output, log real wage, and log labor productivity. The results are presented in Table 6. Each cell corresponds to a separate regression of tariff levels on the industry characteristic reported in the column. The first panel reports correlation between export tariffs (U.S. tariffs) in 1991 and Mexican industry characteristics in 1987 as well as the change in these characteristics over the 1987-1990 period. The second panel reports correlations between import tariffs (Mexican tariffs) in 1991 and these same characteristics. We find no significant correlation between pre-reform industry characteristics and initial tariff values.[24]

As an additional check we have also run regressions which include controls for six-digit CMAP industry characteristics that may be correlated with changes in export tariffs. To avoid potential endogeneity we use U.S. industry characteristics. In particular, we use data from the NBER manufacturing database and control for industry capital/labor ratio and industry productivity (measured as valued-added/labor). The inclusion of these variables has no impact on the main

[23] Our main results are little changed if we use initial tariff levels as instruments for actual tariff changes. Results are available in the on-line appendix Table C6.

[24] We also do not find a significant correlation between pre-reform industry characteristics and tariff changes between 1991 and 2000.

coefficients of interest.[25]

Another potentially important omitted variable is the initial level of female shares. Aguayo, Airola, Juhn, and Villegas-Sanchez (2013) study the between-industry shifts in labor allocation due to trade, and find that tariff declines, at least the more aggregate 3-digit level, were larger in sectors with higher initial female share. Tariff changes led to expansions of female intensive sectors and this contributed to the overall increase in female labor share in the economy. It is in turn plausible that initial female shares could be correlated with subsequent changes in female shares. One possibility is reversion to the mean: if higher initial shares mean limited possibility for future growth in these shares, this implies a negative correlation between changes and initial levels. Given the positive correlation between tariff changes and initial levels, this would bias the coefficients on tariff changes in our regressions towards zero. Thus, in the presence of reversion to the mean, our findings above indicate particularly strong effects. Another possibility is that changes in female shares might be larger when initial levels are already high. This would bias our regressions in the opposite direction, and could potentially explain away our results. We address this possibility in two ways, by using an industry-level measure of female intensive sectors, and by including the initial value of relative female employment or wages at the firm level.

A recent paper by Do, Levchenko, and Raddatz (2011) classifies sectors as female or male intensive based on the average share of female workers in total employment across countries. We include this measure as an additional control and find our results are somewhat stronger with the inclusion of this variable. We also interact this measure with tariff changes and find no significant interactions between the two variables (see results in the on-line appendix Table C8). These results indicate that the correlation between initial sector female intensity and tariff changes does not drive our main findings. We perform similar exercises including the initial share of female to male employment in blue or white collar occupations at the firm level (Table C9 in the on-line appendix). We find that our results on employment and wage bill are robust, although the wage results are not. Overall, these results indicate that the correlation between initial female intensity and tariff changes is not driving the within-industry shifts towards female labor documented here.

[25] Results are available in the on-line appendix Table C7.

5.4 Alternative Channels

In this section we explore alternative channels which may be driving our results. Note that any alternative story would have to explain both the differential change in female outcomes by export status and by occupation category. For example, a supply-side model based on an increase in women's education level over this period could explain an overall increase in relative wages, but would have a hard time explaining the differential changes we find. Only if women's education increased disproportionately in blue collar tasks could an education channel be driving our results.[26]

An alternative model which would be consistent with our findings is one where men and women do not differ in skills, but women have higher reservation wages. If the new technology adopted by exporters increases the demand for blue-collar workers, the resulting increase in blue-collar wages could induce more women to work. This alternative story would imply that blue-collar wages should rise overall. As we report in table B1 in the on-line appendix, however, we find no evidence that blue-collar wages (averaging over both men and women) grew faster in newly-exporting firms. We also do not find evidence that blue-collar wages overall grew faster in firms with more rapid technology upgrading (results available upon request). This suggests that, consistent with our model, the new technology did not raise the overall returns to blue-collar workers.

Another possible alternative mechanism is through foreign direct investment (FDI). It may be the case that the new exporters are more likely to be foreign firms who not only bring newer technology but also less discriminatory attitudes towards hiring women. This could explain our findings if there was a change in discrimination among blue-collar but not white-collar workers.[27]

[26] An interesting possibility is that the mechanism we are proposing could yield improvements in schooling levels if the higher demand for blue collar women induced them to acquire education. Atkin (2012) studies the impact of exports on schooling in Mexico over this period, and finds that an arrival of high skill jobs, defined as those employing the upper 1/3rd of the distribution of schooling attainment in a local labor market, led to an increase in education. At the same time, the arrival of low skill jobs, which employ the lowest 1/3rd of the schooling distribution, caused students to drop out of school. Our results suggest that it would also be interesting to look at these effects by occupation and gender. To address this directly here would require firm-level information on workers' education levels before and after trade liberalization, which is not available in our data. We also do not have municipal identifiers that would allow us to merge our data with Atkin's.

[27] We are not aware of existing models of discrimination that would predict this. For example Goldin (2002) model, where workers care about how their abilities are perceived by outsiders, would suggest the opposite: that

Testing this formally is difficult, since foreign firms may also be more likely to represent upgraded technology. Thus, an increase in foreign ownership could be entirely consistent with our model.

To test whether changes in foreign ownership can explain our results, we estimate the following equation:

$$\begin{aligned} \Delta FemaleRatio_{i,s} &= \beta_1 \Delta ExportTariff_s + \beta_2 \Delta Foreign_{i,s} \\ &\quad + \beta_x X_{i,s,1991} + \delta_{s'} + \Delta\epsilon_{i,s} \end{aligned} \tag{14}$$

where $\Delta Foreign_{i,s}$ refers to the change in foreign ownership status. Following the official balance-of-payment definition of FDI, we define foreign ownership equal to 1 if foreign ownership is above 10%. The results are reported in Table 7. Adding the change in foreign ownership status does not affect our wage results, but it does reduce the size of our coefficients for employment and wage bill. For example, the effect of tariffs changes on wage bill share is reduced from -0.046 (Table 5, column (5)) to -0.033 in column (5) of Table 7. Could this reflect changes in discriminatory attitudes? To investigate this further Table C5 in the on-line appendix examines employer hiring preferences by foreign ownership status. We find little difference in the gender preferences expressed by foreign and domestic firms in the various occupation categories. We take this as supporting evidence that changes in technology, and not changing discrimination against women, account for the differential effect by foreign ownership status.

Another possible channel is import tariffs. Reductions in import tariffs may subject domestic firms to competition and spur technological innovation (for example, as in Bloom, Draca, and Van Reenen (2011) or Csillag and Koren (2011)). To the extent that the reductions in import and export tariffs are positively correlated across industries, we may be capturing the impact of import tariffs. We examine this possibility directly by replacing $\Delta ExportTariff_s$ with $\Delta ImportTariff_s$ and report the results in Table 8.[28] As the first panel illustrates, there is no systematic relationship between import tariff reductions and women's relative outcomes. In the second panel, we include both export and import tariffs, and again show that the effect is driven by the former, with the

discrimination is generally higher among white-collar workers. In blue collar jobs, where physical strength in an obvious requirement, there is less of a need to signal high ability through discrimination, while asymmetric information about the skills required for white-collar tasks may make discrimination worthwhile.

[28] $ImportTariff_s$ refers to tariffs on final goods.

coefficient estimates changing very little compared to Table 5.

Another channel through which import tariffs could impact outcomes is by affecting the prices of imported inputs. Recent papers by Amiti and Konings (2007) and Topalova and Khandelwal (2011) find that trade reform lowered the tariffs on imported inputs which increased productivity among domestic firms. Unfortunately we were not able to locate detailed industry level (CMAP) input-output tables for Mexico during that period that would allow us to link import tariff changes to sectors that would be most impacted. However, we conduct the exercise using 2-digit industry level input-output data provided by the World Input-Output Database.[29] We use input-output coefficients to construct a weighted average of tariff changes. For example, if according to the input-output table, sector 38 (Machinery and Equipment) obtains 60 percent of its inputs from sector 37 (Metals) and 40 percent from sector 36 (Non-Metals) we multiply the change in import tariffs in sector 37 between 1991 and 2000 by 0.6 and the change in import tariffs in sector 36 by 0.4 to obtain a weighted average of input tariffs. In addition, although we do not have firm information on the percentage of inputs imported by sector we do know whether the firm imported intermediate inputs or not. We estimate the following equation (similar to Amiti and Konings (2007)):

$$\begin{aligned} \Delta FemaleRatio_{i,s} = {} & \beta_1 \Delta ExportTariffs_s + \beta_2 Importer_{i,s,2000} \\ & + \beta_3 \Delta InputTariffs_{s'} \times Importer_{i,s,2000} + \\ & + \beta_x X_{i,s,1991} + \delta_{s'} + \Delta\epsilon_{i,s} \end{aligned} \tag{15}$$

We report the results of this robustness check in Table 9. Notice that while export tariffs are available at the 6-digit industry classification, input tariffs are constructed at the 2-digit industry level and therefore, the direct effect is captured by the industry fixed effects. The import tariff coefficient and the interaction term are not statistically significant while the export tariff coefficients change little. Similar results are obtained if the variable $Importer_{i,s,2000}$ is substituted by initial importer condition (i.e., whether the firm imported in 1991) or the change in import status between 1991 and 2000. While admittedly our construction of input price changes based on 2-digit level input-output data are less than ideal, we conclude that there is little evidence that changes in the price of imported inputs are driving our results.

[29]The data can be found at http://www.wiod.org/

5.5 Effects of Technology on Gender Outcomes: Instrumental Variables

We have shown that reductions in export tariffs are associated with larger within-firm increases in the relative employment and wage bill share of women in blue-collar occupations. We attribute these effects to technology upgrading among exporting firms which complements female workers. We have shown that tariff reductions increase the number of exporting firms and also increase these firms' investment in upgraded technology. This suggests a causal mechanism where trade reform induces technology upgrading which favors female workers. In the previous section, we argued that alternative theories are unlikely to fully account for our findings.

Our results have two possible interpretations. The first one is that we have identified a reduced form effect of tariff reductions leading to gender outcomes. This is in and of itself an important empirical finding which has far-reaching policy implications, showing that trade liberalization has the potential to reduce gender inequality. Furthermore, we have modeled a novel mechanism which can explain this effect and find direct evidence supporting this mechanism in the data. Tariff changes induce firms to export and upgrade technology in a manner consistent with our model.

The second interpretation is that, at least in the context of Mexican trade liberalization, our mechanism based on technology upgrading is the only channel through which tariffs impact gender outcomes. Under this strong assumption, tariff changes meet the exclusion restriction to serve as an instrument for technology upgrading. Thus we can go one step further, and estimate the impact of technology upgrading on gender inequality. For the interested reader, we conduct the instrumental variables regression and report the results in Table 10. Our point estimates imply that a 10 percent faster growth in the value of machinery increases the growth of female employment and wage bill share in the blue-collar category by 6.5 percent and 7.6 percent, respectively, and the growth of the female-male wage ratio by 2.4 percent.

6 Conclusion

We presented a model where trade liberalization induced exporting firms to upgrade their technology in a way that raised the relative productivity of women in blue-collar occupations. Our empirical findings using firm-level data from Mexico are consistent with the model. We found that firms experiencing larger declines in export tariffs were more likely to hire blue-collar women and to pay them higher wages. We did not find similar effects in white-collar occupations, where the relative importance of physically demanding skills is less likely to have changed. Consistent with the model, we showed that these improvement in blue-collar women's labor market outcomes were driven by firms newly entering the export markets who upgraded their technology towards new computerized production machinery. These results suggest an important channel through which current trade liberalization efforts can affect gender inequality.

Acknowledgements

We would like to thank Yona Rubinstein, Nathan Nunn and Peter Morrow for their thoughtful discussions of an earlier version of the paper. We also want to thank Eric Verhoogen and seminar participants at LSE, Dalhousie, the LACEA-Conference of the Trade and Integration Growth Network, and the 18th Annual Empirical Investigations in International Trade. Carolina Villegas-Sanchez is thankful to Gerardo Leyva, Abigail Duran and Adriana Ramirez for granting access to INEGI data at the offices of INEGI in Aguascalientes under the commitment of complying with the confidentiality requirements set by the Mexican Laws. Special thanks to all INEGI employees that provided assistance and in particular to Gabriel Romero. Carolina Villegas-Sanchez acknowledges financial support from Banco Sabadell.

References

Aguayo, E., J. Airola, C. Juhn, and C. Villegas-Sanchez (2013): "Did Trade Liberalization Help Women? The Case of Mexico in the 1990s," *Research in Labor Economics*, forthcoming.

Alesina, A., P. Giuliano, and N. Nunn (2011): "On the Origins of Gender Roles: Women and the Plough," working paper, Harvard University.

Amiti, M., and D. Davis (2012): "Trade, Firms, and Wages: Theory and evidence," *Review of Economic Studies*, 79(1), 1–36.

Amiti, M., and J. Konings (2007): "Trade Liberalization, Intermediate Inputs, and Productivity: Evidence from Indonesia," *American Economic Review*, 97(5), 1611–1638.

Atkin, D. (2012): "Endogenous Skill Acquistion and Export Manufacturing in Mexico," NBER working paper number 18266.

Attanasio, O., P. Goldberg, and N. Pavcnik (2004): "Trade Reforms and Wage Inequality in Colombia," *Journal of Development Economics*, 74(2), 331–366.

Autor, D., F. Levy, and R. Murnane (2003): "The Skill Content of Recent Technological Change: An Empirical Exploration," *Quarterly Journal of Economics*, 118(4), 1279–1333.

Becker, G. (1957): *The Economics of Discrimination*. University of Chicago Press.

Behrman, J., N. Birdsall, and M. Székely (2000): "Economics Reform and Wage Differentials in Latin America," RES Working Papers 4235, Inter-American Development Bank, Research Department.

Bernard, A., and B. Jensen (1999): "Exceptional Exporter Performance: Cause, Effect, or Both?," *Journal of International Economics*, 47(1), 1–25.

Black, S., and E. Brainerd (2004): "Importing Inequality? The Impact of Globalization on Gender Discrimination," *Industrial and Labor Relations Review*, 57(4), 540–559.

Blau, F., and L. Kahn (1997): "Swimming Upstream: Trends in the Gender Wage Differential in the 1980s," *Journal of Labor Economics*, 15(1), 1–42.

Bloom, N., M. Draca, and J. Van Reenen (2011): "Trade Induced Technical Change: The Impact of Chinese Imports on Innovation, Diffusion and Productivity," working paper, Stanford University.

Brambilla, I., D. Lederman, and G. Porto (2012): "Exports, Export Destinations, and Skills," *American Economic Review*, 102(7), 3406–3438.

Bustos, P. (2011a): "Trade Liberalization, Exports, and Technology Upgrading: Evidence on the Impact of MERCOSUR on Argentinian Firms," *American Economic Review*, 101(1), 304–340.

——— (2011b): "The Impact of Trade on Technology and Skill Upgrading: Evidence from Argentina," working paper, Universitat Pompeu Fabra.

Cragg, M., and M. Epelbaum (1996): "Why has Wage Dispersion Grown in Mexico? Is it the Incidence of Reforms or the Growing Demand for Skills?," *Journal of Development Economics*, 51(1), 99–116.

Csillag, M., and M. Koren (2011): "Machines and Machinist: Capital-Skill Complementarity from an International Trade Perspective," working paper, Central European University.

Do, Q., A. Levchenko, and C. Raddatz (2011): "Engendering trade," Policy Research Working Paper Series 5777, The World Bank.

Duflo, E. (2003): "Grandmothers and Granddaughters: Old Age Pension and Intra-household Allocation in South Africa," *World Bank Economic Review*, 17(1), 1–25.

——— (2012): "Womens Empowerment and Economic Development," *Journal of Economic Literature*, 50(4), 1051–1079.

Ederington, J., J. Minier, and K. Troske (2010): "Where the Girls Are: Trade and Labor Market Segregation in Colombia," University of Kentucky, Lexington, KY, USA.

Feliciano, Z. (2001): "Workers and Trade Liberalization: The Impact of Trade Reforms in Mexico on Wages and Employment," *Industrial and Labor Relations Review*, 55, 95–115.

Frias, J., D. Kaplan, and E. Verhoogen (2009): "Exports and Wage Premia: Evidence from Mexican Employer-Employee Data," working paper, Columbia University.

Galor, O., and D. N. Weil (1996): "The Gender Gap, Fertility, and Growth," *American Economic Review*, 86(3), 374–387.

Goldberg, P., and N. Pavcnik (2007): "Distributional Effects of Globalization in Developing Countries," *Journal of Economic Literature*, 45, 39–82.

Goldin, C. (2002): "A Pollution Theory of Discrimination: Male and Female Differences in Occupations and Earnings," NBER working paper 8985.

Hanson, G., and A. Harrison (1999): "Trade Liberalization and Wage Inequality in Mexico," *Industrial and Labor Relations Review*, 52(2), 271–288.

Helpman, E., O. Itskhoki, and S. Redding (2010): "Inequality and Unemployment in a Global Economy," *Econometrica*, 4(78), 1239–1283.

——— (2011): "Trade and Labor Market Outcomes," National Bureau of Economic Research working paper number 16662.

Iacovone, L., and B. Javorcik (2010): "Multi-Product Exporters: Product Churning, Uncertainty and Export Discoveries," *The Economic Journal*, 120(544), 481–499.

Juhn, C., G. Ujhelyi, and C. Villegas-Sanchez (2013): "Trade and Gender Inequality," *American Economic Review Papers and Proceedings*, 103(3), 269–273.

Melitz, M. (2003): "The Impact of Trade on Intra-Industry Reallocations and Aggregate Industry Productivity," *Econometrica*, 71(6), 1695–1725.

Oostendorp, R. (2009): "Globalization and the Gender Wage Gap," *World Bank Economic Review*, 23(1), 141–161.

Ozler, S. (2000): "Export Orientation and Female Share of Employment: Evidence from Turkey," *World Development*, 28(7), 1239–1248.

Pavcnik, N. (2003): "What Explains Skill Upgrading in Less-Developed Countries?," *Journal of Development Economics*, 71(2), 311–328.

Qian, N. (2008): "Missing Women and the Price of Tea in China: The Effect of Sex-Specific Earnings on Sex Imbalance," *Quarterly Journal of Economics*, 123(3), 1251–1285.

Rendall, M. (2010): "Brain versus Brawn: The Realization of Women's Comparative Advantage," working paper, University of Zurich.

Revenga, A. (1997): "Employment and Wage Effects of Trade Liberalization: The Case of Mexican Manufacturing," *Journal of Labor Economics*, 15(S3), 20–43.

Robertson, R. (2004): "Relative Prices and Wage Inequality: Evidence from Mexico," *Journal of International Economics*, 64(2), 387–409.

Saure, P., and H. Zoabi (2011): "International Trade, the Gender Gap, Fertility and Growth," working paper.

Thomas, D. (1990): "Intra-household Resource Allocation: An Inferential Approach," *The Journal of Human Resources*, 25(4), 635–664.

Topalova, P., and A. Khandelwal (2011): "Trade liberalization and firm productivity: The case of India," *The Review of Economics and Statistics*, 93(3), 995–1009.

Verhoogen, E. (2008): "Trade, Quality Upgrading, and Wage Inequality in the Mexican Manufacturing Sector," *Quarterly Journal of Economics*, 123(2), 489–530.

Weinberg, B. (2000): "Computer Use and the Demand for Female Workers," *Industrial and Labor Relations Review*, 53, 290–308.

Zabludovsky, J. (2005): "El TLCAN y la política de comercio exterior en México: una agenda inconclusa," *INFORMACION COMERCIAL ESPANOLA-MONTHLY EDITION-*, 821, 59.

Table 1: Employer Preferences in Hiring by Occupational Category

Panel A: Female-Male Preference (Percentage of Observations)

	Directors		Managers		Specialized Workers		General workers	
	Percent	Obs.	Percent	Obs.	Percent	Obs.	Percent	Obs.
Male Preferred	25.79	818	4.01	922	54.85	877	45.77	911
Female Preferred	0.61	818	4.23	922	3.19	877	4.94	911
Indifferent	73.59	818	91.76	922	41.96	877	49.29	911

Panel B: Reasons for Male Preference

	Director		Manager		Specialized Worker		General Worker	
	Freq.	Percent	Freq.	Percent	Freq.	Percent	Freq.	Percent
Heavy Work	10	4.63	8	10.53	336	66.01	376	81.39
Lower Absenteeism	18	8.33	13	17.11	10	1.96	8	1.73
Special Abilities	88	40.74	20	26.32	114	22.4	40	8.66
Higher Productivity	14	6.48	13	17.11	15	2.95	17	3.68
Higher Adaptability	35	16.2	13	17.11	18	3.54	10	2.16
Higher Control	30	13.89	4	5.26	7	1.38	3	0.65
Lower external turnover	11	5.09	3	3.95	3	0.59	2	0.43
Other	10	4.63	2	2.63	6	1.18	6	1.3
Total	216	100	76	100	509	100	462	100

Notes: Panel A reports the percentage of firms that expressed a gender preference when hiring according to occupational category in 2000. Obs. refers to the total number of firms and it varies across occupational categories because it is based on those firms that hired in that year and occupational category (only firms that hired were asked about their gender preferences). Panel B reports the distribution of firms according to the main reasons expressed in 2000 for preferring men over women according to occupational category.

Table 2: Tariff Changes and Exports

	Dependent variable: Change in Export Status and Percentage of Exports			
	NewExporter (1)	NewExporter (2)	$\Delta ShareExports$ (3)	$\Delta ShareExports$ (4)
Δ Export Tariff	-0.038***	-0.042***	0.017	-0.227
	(0.008)	(0.008)	(0.431)	(0.445)
$ln(K/VA)_{init}$		-0.023*		-0.682
		(0.012)		(0.894)
$ln(VA)_{init}$		-0.004		2.667**
		(0.009)		(1.074)
$R\&Dshare_{init}$		-0.001		-0.103
		(0.001)		(0.072)
$Foreign_{init}$		-0.075*		5.780**
		(0.040)		(2.063)
Observations	920	904	527	516
R^2	.054	.068	.052	.097
Sector2dig Fixed Effects	Yes	Yes	Yes	Yes

Notes: Standard errors clustered at cmap level in parentheses. New Exporter refers to those firms that did not export in 1991 but are exporting in 2000. $\Delta ShareExports$ refers to the change between 2000 and 1991 in the share of export revenue in total sales. Columns (1) and (2) include all firms in the analysis. Columns (3) and (4) refer only to those firms that report export revenue in 2000. Δ Export Tariff indicates the change in sectoral tariffs (6-digit sector classification) applied by the US between 2000 and 1991. $ln(K/VA)_{init}$ is the log of total assets to value added in 1991. $ln(VA)_{init}$ is the log value added in 1991. $R\&Dshare_{init}$ is the share of R&D spending in total income in 1991. $Foreign_{init}$ is a dummy variable that takes the value of one if the firm was more than 10 percent owned by foreign-owned investors in 1991 and zero otherwise. *** , **, *, denote significance at 1%, 5%, 10% levels.

Table 3: Export Status and Technology Upgrading

	Dependent variable: Technology Outcomes					
	(1)	(2)	(3)	(4)	(5)	(6)
	Machinery Value Growth	Machinery Value Growth	Technology Upgraded Machinery Value Growth	Technology Upgraded Machinery Value Growth	Non-Upgraded Machinery Value Growth	Non-Upgraded Machinery Value Growth
Continuing Exporters	-0.143	0.196	0.065	0.180*	-0.217**	-0.014
	(0.138)	(0.140)	(0.085)	(0.092)	(0.106)	(0.111)
New Exporters	0.243*	0.356**	0.151*	0.187**	0.065	0.133
	(0.141)	(0.132)	(0.078)	(0.080)	(0.114)	(0.110)
Stop Exporters	-0.343*	-0.114	-0.129	-0.055	-0.208	-0.066
	(0.179)	(0.194)	(0.124)	(0.131)	(0.126)	(0.133)
$ln(K/VA)_{init}$		-0.535***		-0.166***		-0.350***
		(0.046)		(0.029)		(0.041)
$ln(VA)_{init}$		-0.228***		-0.074**		-0.130***
		(0.045)		(0.030)		(0.035)
$Foreign_{init}$		0.358**		0.115		0.223**
		(0.118)		(0.092)		(0.089)
Observations.	936	920	936	920	936	920
R^2	.033	.22	.018	.068	.032	.17
Sector2dig Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes

Notes: Standard errors clustered at cmap level in parentheses. Continuing exporters are those firms that exported in 1991 and 2000. New exporters are those firms that did not export in 1991 but export in 2000. Stop Exporters are firms that exported in 1991 but do not export in 2000. The omitted category is Non-Exporter. Machinery Value Growth is the log change in the value of machinery and equipment between 1991 and 2000. Technology Upgraded Machinery Growth refers to the product of the log difference in the value of machinery and equipment between 2000 and 1991 and a dummy variable that equals one if the machinery and equipment acquired since 1999 is automatic/computerized and it is new machinery imported from developed countries. The Non-Upgraded Machinery equals one if the machinery and equipment acquired since 1999 is not automatic/computerized or it is not new machinery imported from developed countries. $ln(K/VA)_{init}$ is the log of total assets to value added in 1991. $ln(VA)_{init}$ is the log value added in 1991. $Foreign_{init}$ is a dummy variable that takes the value of one if the firm was more than 10 percent owned by foreign-owned investors in 1991 and zero otherwise. *** , **, *, denote significance at 1%, 5%, 10% levels.

Table 4: Tariff Changes and Technology Upgrading

	Dependent variable: Technology Outcomes					
	(1) Machinery Value Growth	(2) Machinery Value Growth	(3) Technology Upgraded Machinery Value Growth	(4) Technology Upgraded Machinery Value Growth	(5) Non-Upgraded Machinery Value Growth	(6) Non-Upgraded Machinery Value Growth
Δ Export Tariff	-0.019	-0.070**	-0.044**	-0.061***	0.024	-0.009
	(0.027)	(0.022)	(0.016)	(0.016)	(0.022)	(0.020)
$ln(K/VA)_{init}$		-0.549***		-0.170***		-0.360***
		(0.045)		(0.029)		(0.040)
$ln(VA)_{init}$		-0.207***		-0.055**		-0.133***
		(0.043)		(0.028)		(0.034)
$Foreign_{init}$		0.389**		0.136		0.225**
		(0.118)		(0.093)		(0.087)
Observations	918	902	918	902	918	902
R^2	.023	.22	.024	.079	.025	.16
Sector2dig Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes

Notes: Standard errors clustered at cmap level in parentheses. Δ Export Tariff indicates the change in sectoral tariffs (6-digit sector classification) applied by the US between 2000 and 1991. Machinery Value Growth is the log change in the value of machinery and equipment between 1991 and 2000. Technology Upgraded Machinery Growth refers to the product of the log difference in the value of machinery and equipment between 2000 and 1991 and a dummy variable that equals one if the machinery and equipment acquired since 1999 is automatic/computerized and it is new machinery imported from developed countries. The Non-Upgraded Machinery equals one if the machinery and equipment acquired since 1999 is not automatic/computerized or it is not new machinery imported from developed countries. $ln(K/VA)_{init}$ is the log of total assets to value added in 1991. $ln(VA)_{init}$ is the log value added in 1991. $Foreign_{init}$ is a dummy variable that takes the value of one if the firm was more than 10 percent owned by foreign-owned investors in 1991 and zero otherwise. *** , **, *, denote significance at 1%, 5%, 10% levels.

Table 5: Reduced Form: Tariff Changes and Female-Male Labor Outcomes

	Dependent variable: Growth in Female-Male Labor Ratios								
	White Collar			Blue Collar			All		
	Female-Male Employment Growth (1)	Female-Male Wage Bill Growth (2)	Female-Male Wage Growth (3)	Female-Male Employment Growth (4)	Female-Male Wage Bill Growth (5)	Female-Male Wage Growth (6)	Female-Male Employment Growth (7)	Female-Male Wage Bill Growth (8)	Female-Male Wage Growth (9)
Δ Export Tariff	0.020	0.012	-0.010	-0.040*	-0.046**	-0.010*	0.020	0.012	-0.010
	(0.025)	(0.024)	(0.007)	(0.022)	(0.021)	(0.005)	(0.025)	(0.024)	(0.007)
$\Delta ExportTariff \times Blue$							-0.060**	-0.058*	-0.001
							(0.027)	(0.030)	(0.010)
$Blue$							0.142	0.092	-0.083
							(0.691)	(0.670)	(0.243)
$ln(K/VA)_{init}$	0.026	0.021	-0.014	0.004	0.019	0.009	0.026	0.021	-0.014
	(0.040)	(0.039)	(0.015)	(0.046)	(0.047)	(0.015)	(0.040)	(0.039)	(0.015)
$ln(VA)_{init}$	-0.028	-0.024	-0.005	-0.055	-0.058	-0.007	-0.028	-0.024	-0.005
	(0.041)	(0.039)	(0.017)	(0.050)	(0.051)	(0.013)	(0.041)	(0.039)	(0.017)
$R\&Dshare_{init}$	0.009**	0.008**	-0.001	-0.001	-0.001	0.001	0.009**	0.008**	-0.001
	(0.003)	(0.003)	(0.001)	(0.004)	(0.004)	(0.001)	(0.003)	(0.003)	(0.001)
$Foreign_{init}$	0.001	-0.001	0.010	-0.038	-0.005	0.032	0.001	-0.001	0.010
	(0.117)	(0.114)	(0.063)	(0.159)	(0.163)	(0.051)	(0.117)	(0.114)	(0.063)
$ln(K/VA)_{init} \times Blue$							-0.022	-0.003	0.023
							(0.059)	(0.058)	(0.020)
$ln(VA)_{init} \times Blue$							-0.027	-0.033	-0.003
							(0.055)	(0.055)	(0.019)
$R\&Dshare_{init} \times Blue$							-0.011**	-0.009**	0.002
							(0.004)	(0.004)	(0.002)
$Foreign_{init} \times Blue$							-0.038	-0.004	0.022
							(0.187)	(0.200)	(0.080)
Observations	899	898	862	895	895	562	1794	1793	1424
R^2	.026	.02	.019	.0095	.012	.021	.013	.012	.027
Sector2dig Fixed Effects	yes	yes	yes	yes	yes	yes	yes	yes	yes
$Sector2digFixedEffects \times Blue$	n.a	n.a	n.a	n.a	n.a	n.a	yes	yes	yes
$F-test(\Delta ExportTariff)$	n.a	n.a	n.a	n.a	n.a	n.a	0.0701	0.074	0.031

*Notes:*Standard errors clustered at cmap level in parentheses. Δ Export Tariff indicates the change in sectoral tariffs (6-digit sector classification) applied by the US between 2000 and 1991. Columns (1) to (3) refer to the White-Collar category while columns (4) to (6) refer to the Blue-Collar category. Columns (7) to (9) pool together White-Collar and Blue-Collar observations. Female-Male Employment growth refers to the growth in female to male employment ratios between 1991 and 2000. Female-Male Wage Bill is the growth in female to male wage bill ratios between 1991 and 2000. Female-Male wage is the growth in female to male wage ratios between 1991 and 2000. The wage is computed as the ratio of Wage Bill to Employment. The growth rate is computed as $ln((female-maleratio)+0.001)-ln((female-maleratio)+0.001)_{t-1}$. $Blue$ is a dummy variable that takes the value of one if the ratio of female-male labor outcome refers to blue category. $ln(K/VA)_{init}$ is the log of total assets to value added in 1991. $ln(VA)_{init}$ is the log value added in 1991. $R\&Dshare_{init}$ is the share of R&D spending in total income in 1991. $Foreign_{init}$ is a dummy variable that takes the value of one if the firm was more than 10 percent owned by foreign-owned investors in 1991 and zero otherwise. *** , **, *, denote significance at 1%, 5%, 10% levels.

Table 6: Initial Tariffs and Pre-Reform Industrial Characteristics

Panel A: Tariffs Applied by US

	Log Employment	Log Real Wage Bill	Log Output	Log Labor Productivity	Growth in Output (1987-1990)	Growth in Employment (1987-1990)
	(1)	(2)	(3)	(4)	(5)	(6)
$ExportTariff_{1991}$	-0.027	0.001	-0.043	-0.016	-0.006	0.002
	(0.034)	(0.046)	(0.036)	(0.026)	(0.007)	(0.006)
Observations	107	107	107	107	107	107
R^2	.078	.078	.3	.39	.13	.058
Sector2dig Fixed Effects	yes	yes	yes	yes	yes	yes

Panel B: Tariffs Applied by Mexico

	Log Employment	Log Real Wage Bill	Log Output	Log Labor Productivity	Growth in Output (1987-1990)	Growth in Employment (1987-1990)
	(1)	(2)	(3)	(4)	(5)	(6)
$ImportTariff_{1991}$	0.004	-0.003	0.002	-0.002	0.002	0.001
	(0.010)	(0.012)	(0.010)	(0.008)	(0.003)	(0.002)
Observations	89	89	89	89	89	89
R^2	.067	.061	.32	.36	.16	.041
Sector2dig Fixed Effects	yes	yes	yes	yes	yes	yes

Notes: Each cell corresponds to a separate regression of tariff levels on the industry characteristic reported in the column. Panel A reports results using $ExportTariff_{1991}$ that indicates the level of sectoral tariffs (6-digit sector classification) applied by the US in 1991. Panel B reports results using $ImportTariff_{1991}$ that indicates the level of sectoral tariffs (6-digit sector classification) applied by Mexico in 1991. See TableC1 for a full definition of Export and Import tariffs. Observations: Number of industries according to the CMAP classification. Columns (1) to (4) use sectoral characteristics in 1987 while columns (5) and (6) use the growth rate in sectoral characteristics between 1987 and 1990. Robust standard errors are reported in parentheses. *** , **, *, denote significance at 1%, 5%, 10% levels.

Table 7: Alternative Channel: Foreign Ownership

	Dependent variable: Growth in Female-Male Labor Ratios					
	White Collar			Blue Collar		
	Female-Male Employment Growth (1)	Female-Male Wage Bill Growth (2)	Female-Male Wage Growth (3)	Female-Male Employment Growth (4)	Female-Male Wage Bill Growth (5)	Female-Male Wage Growth (6)
Δ Export Tariff	0.021	0.015	-0.008	-0.026	-0.033	-0.011**
	(0.022)	(0.019)	(0.008)	(0.021)	(0.020)	(0.005)
$\Delta Foreign$	-0.109	-0.118	-0.018	0.336	0.391*	0.122*
	(0.134)	(0.132)	(0.065)	(0.206)	(0.209)	(0.073)
$ln(K/VA)_{init}$	-0.009	0.000	-0.003	-0.003	0.017	0.018
	(0.041)	(0.040)	(0.016)	(0.051)	(0.054)	(0.016)
$ln(VA)_{init}$	-0.027	-0.017	0.004	-0.096**	-0.091*	0.003
	(0.047)	(0.044)	(0.017)	(0.048)	(0.048)	(0.015)
$R\&Dshare_{init}$	0.010**	0.007*	-0.002	0.001	0.002	0.001
	(0.004)	(0.004)	(0.001)	(0.004)	(0.004)	(0.001)
Observations	787	786	758	784	784	497
R^2	.026	.018	.011	.016	.02	.04
Sector2dig Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes

*Notes:*Standard errors clustered at cmap level in parentheses. Δ Export Tariff indicates the change in sectoral tariffs (6-digit sector classification) applied by the US between 2000 and 1991. Columns (1) to (3) refer to the White-Collar category while columns (4) to (6) refer to the Blue-Collar category. Female-Male Employment growth refers to the growth in female to male employment ratios between 1991 and 2000. Female-Male Wage Bill is the growth in female to male wage bill ratios between 1991 and 2000. Female-Male wage is the growth in female to male wage ratios between 1991 and 2000. The wage is computed as the ratio of Wage Bill to Employment. The growth rate is computed as $ln((female - maleratio) + 0.001) - ln((female - maleratio) + 0.001)_{t-1}$. $ln(K/VA)_{init}$ is the log of total assets to value added in 1991. $ln(VA)_{init}$ is the log value added in 1991. $R\&Dshare_{init}$ is the share of R&D spending in total income in 1991. $\Delta Foreign$ is the change in ownership status between 1991 and 2000. *** , **, *, denote significance at 1%, 5%, 10% levels.

Table 8: Alternative Channel: Import Tariffs

Dependent variable: Growth in Female-Male Labor Ratios

Panel A: Import Tariffs

	White Collar			Blue Collar		
	Female-Male Employment Growth (1)	Female-Male Wage Bill Growth (2)	Female-Male Wage Growth (3)	Female-Male Employment Growth (4)	Female-Male Wage Bill Growth (5)	Female-Male Wage Growth (6)
Δ Import Tariff	-0.006	-0.001	0.004	0.018	0.017	-0.005
	(0.013)	(0.012)	(0.007)	(0.019)	(0.020)	(0.005)
$ln(K/VA)_{init}$	0.004	0.010	-0.003	0.008	0.022	0.010
	(0.036)	(0.036)	(0.016)	(0.049)	(0.049)	(0.015)
$ln(VA)_{init}$	-0.039	-0.021	0.007	-0.062	-0.065	-0.006
	(0.042)	(0.039)	(0.018)	(0.054)	(0.054)	(0.015)
$R\&Dshare_{init}$	0.007*	0.006	-0.001	-0.002	-0.001	0.001
	(0.004)	(0.004)	(0.001)	(0.005)	(0.005)	(0.001)
$Foreign_{init}$	-0.047	-0.023	0.031	-0.098	-0.071	0.011
	(0.124)	(0.118)	(0.067)	(0.169)	(0.171)	(0.051)
Observations	837	836	803	833	833	510
R^2	.023	.019	.019	.0092	.01	.021
Sector2dig Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes

Panel B: Export and Import Tariffs

	White Collar			Blue Collar		
	Female-Male Employment Growth (1)	Female-Male Wage Bill Growth (2)	Female-Male Wage Growth (3)	Female-Male Employment Growth (4)	Female-Male Wage Bill Growth (5)	Female-Male Wage Growth (6)
Δ Export Tariff	0.023	0.017	-0.008	-0.044*	-0.050**	-0.009
	(0.024)	(0.023)	(0.007)	(0.026)	(0.025)	(0.007)
Δ Import Tariff	-0.002	0.001	0.003	0.016	0.015	-0.005
	(0.012)	(0.011)	(0.007)	(0.019)	(0.020)	(0.005)
$ln(K/VA)_{init}$	0.002	0.004	-0.009	-0.006	0.008	0.009
	(0.041)	(0.040)	(0.016)	(0.049)	(0.050)	(0.016)
$ln(VA)_{init}$	-0.038	-0.023	0.007	-0.055	-0.056	-0.006
	(0.040)	(0.038)	(0.018)	(0.052)	(0.052)	(0.015)
$R\&Dshare_{init}$	0.011**	0.009**	-0.001	0.001	0.001	0.001
	(0.004)	(0.004)	(0.001)	(0.005)	(0.004)	(0.001)
$Foreign_{init}$	0.015	0.030	0.025	-0.069	-0.051	0.007
	(0.120)	(0.115)	(0.068)	(0.165)	(0.169)	(0.052)
Observations.	820	819	789	816	816	504
R^2	.033	.027	.02	.012	.014	.024
Sector2dig Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes

Notes: Standard errors clustered at cmap level in parentheses. Δ Export Tariff indicates the change in sectoral tariffs (6-digit sector classification) applied by the US between 2000 and 1991. Δ Import Tariff indicates the change in sectoral tariffs (6-digit sector classification) applied by Mexico between 2000 and 1991. Columns (1) to (3) refer to the White-Collar category while columns (4) to (6) refer to the Blue-Collar category. Female-Male Employment growth refers to the growth in female to male employment ratios between 1991 and 2000. Female-Male Wage Bill is the growth in female to male wage bill ratios between 1991 and 2000. Female-Male wage is the growth in female to male wage ratios between 1991 and 2000. The wage is computed as the ratio of Wage Bill to Employment. The growth rate is computed as $ln((female-maleratio)+0.001) - ln((female-maleratio)+0.001)_{t-1}$. $ln(K/VA)_{init}$ is the log of total assets to value added in 1991. $ln(K/VA)_{init}$ is the log of total assets to value added in 1991. $ln(VA)_{init}$ is the log value added in 1991. $R\&Dshare_{init}$ is the share of R&D spending in total income in 1991. $Foreign_{init}$ is a dummy variable that takes the value of one if the firm was more than 10 percent owned by foreign-owned investors in 1991 and zero otherwise. *** , **, *, denote significance at 1%, 5%, 10% levels.

Table 9: Alternative Channel: Input Tariffs

	Dependent variable: Growth in Female-Male Labor Ratios					
	White Collar			Blue Collar		
	Female-Male Employment Growth (1)	Female-Male Wage Bill Growth (2)	Female-Male Wage Growth (3)	Female-Male Employment Growth (4)	Female-Male Wage Bill Growth (5)	Female-Male Wage Growth (6)
Δ Export Tariff	0.021	0.011	-0.010	-0.040*	-0.047**	-0.011*
	(0.025)	(0.024)	(0.007)	(0.022)	(0.022)	(0.006)
$\Delta InputTariff \times Importer$	0.208	0.016	-0.124	-0.197	-0.224	-0.037
	(0.385)	(0.360)	(0.164)	(0.565)	(0.560)	(0.130)
$Importer$	0.080	0.018	-0.017	-0.083	-0.087	-0.013
	(0.229)	(0.214)	(0.086)	(0.345)	(0.346)	(0.082)
$ln(K/VA)_{init}$	0.028	0.021	-0.015	0.003	0.017	0.009
	(0.040)	(0.039)	(0.015)	(0.045)	(0.047)	(0.015)
$ln(VA)_{init}$	-0.026	-0.025	-0.006	-0.057	-0.059	-0.008
	(0.042)	(0.039)	(0.017)	(0.051)	(0.051)	(0.013)
$R\&Dshare_{init}$	0.010**	0.008**	-0.001	-0.001	-0.001	0.001
	(0.003)	(0.003)	(0.001)	(0.004)	(0.004)	(0.001)
$Foreign_{init}$	0.001	-0.002	0.009	-0.037	-0.005	0.032
	(0.115)	(0.113)	(0.063)	(0.160)	(0.164)	(0.051)
Observations	899	898	862	895	895	562
R^2	.026	.02	.02	.0096	.012	.021
F-test(Importer)	.83	.99	.43	.93	.89	.93
Sector2dig Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes

Notes: Standard errors clustered at cmap level in parentheses. Δ Export Tariff indicates the change in sectoral tariffs (6-digit sector classification) applied by the US between 2000 and 1991. Δ Input Tariff is the change between 2000 and 1991 in the variable input tariff. Input tariffs are calculated for each industry k as a weighted average of all tariffs applied by sectors other than k, with the weights based on the national input-output coefficients in 1995, constructed at the 2 digit sectoral level. $Importer$ is a dummy variable that equals one if the firm imported intermediate inputs in 2000. Columns (1) to (3) refer to the White-Collar category while columns (4) to (6) refer to the Blue-Collar category. Female-Male Employment growth refers to the growth in female to male employment ratios between 1991 and 2000. Female-Male Wage Bill is the growth in female to male wage bill ratios between 1991 and 2000. Female-Male wage is the growth in female to male wage ratios between 1991 and 2000. The wage is computed as the ratio of Wage Bill to Employment. The growth rate is computed as $ln((female-maleratio)+0.001)-ln((female-maleratio)+0.001)_{t-1}$. $ln(K/VA)_{init}$ is the log of total assets to value added in 1991. $ln(K/VA)_{init}$ is the log of total assets to value added in 1991. $ln(VA)_{init}$ is the log value added in 1991. $R\&Dshare_{init}$ is the share of R&D spending in total income in 1991. $Foreign_{init}$ is a dummy variable that takes the value of one if the firm was more than 10 percent owned by foreign-owned investors in 1991 and zero otherwise. *** , **, *, denote significance at 1%, 5%, 10% levels.

Table 10: Technology Upgrading and Female-Male Labor Outcomes (IV)

Panel A: Second Stage			
	Dependent variable: Growth in Female-Male Labor Ratios in the Blue-Collar Category		
	Female-Male Employment Growth (1)	Female-Male Wage Bill Growth (2)	Female-Male Wage Growth (3)
Technology Upgraded Machinery Growth	0.652*	0.763*	0.242
	(0.395)	(0.392)	(0.157)
$ln(K/VA)_{init}$	0.117	0.150*	0.049*
	(0.081)	(0.079)	(0.028)
$ln(VA)_{init}$	-0.020	-0.016	0.008
	(0.051)	(0.052)	(0.017)
$R\&Dshare_{init}$	0.000	0.001	0.001
	(0.005)	(0.005)	(0.001)
$Foreign_{init}$	-0.130	-0.113	-0.001
	(0.174)	(0.181)	(0.064)
Observations	895	895	562

Panel B: First Stage			
	Dependent variable: Technology Upgraded Machinery Value Growth		
	(1)	(2)	(3)
Δ Export Tariff	-0.061***	-0.061***	-0.043**
	(0.012)	(0.012)	(0.006)
Observations	895	895	562
Tests			
F-Test	26.37	26.37	6.56
Anderson	3.24	4.72	3.6
Cragg-Donald	26.375	26.375	6.564

*Notes:*Standard errors clustered at cmap level in parentheses. Panel A reports the results from the Second Stage. Panel B reports the results from the First Stage. Δ Export Tariff indicates the change in sectoral tariffs (6-digit sector classification) applied by the US between 2000 and 1991. Technology Upgraded Machinery Growth refers to the product of the log difference in the value of machinery and equipment between 2000 and 1991 and a dummy variable that equals one if the machinery and equipment acquired since 1999 is automatic/computerized and it is new machinery imported from developed countries. Female-Male Employment growth refers to the growth in female to male employment ratios between 1991 and 2000. Female-Male Wage Bill is the growth in female to male wage bill ratios between 1991 and 2000. Female-Male wage is the growth in female to male wage ratios between 1991 and 2000. The wage is computed as the ratio of Wage Bill to Employment. The growth rate is computed as $ln((female - maleratio) + 0.001) - ln((female - maleratio) + 0.001)_{t-1}$. $ln(K/VA)_{init}$ is the log of total assets to value added in 1991. $ln(VA)_{init}$ is the log value added in 1991. $R\&Dshare_{init}$ is the share of R&D spending in total income in 1991. $Foreign_{init}$ is a dummy variable that takes the value of one if the firm was more than 10 percent owned by foreign-owned investors in 1991 and zero otherwise. *** , **, *, denote significance at 1%, 5%, 10% levels.

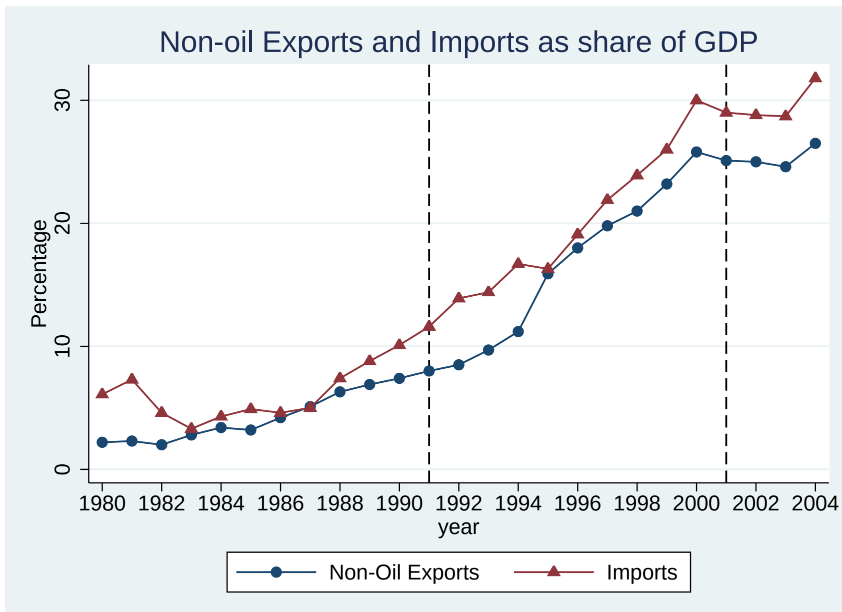

Figure 1: Mexican Imports and Exports. *Source:* Balance of Payment information provided by the Central Bank of Mexico (Banco de Mexico).

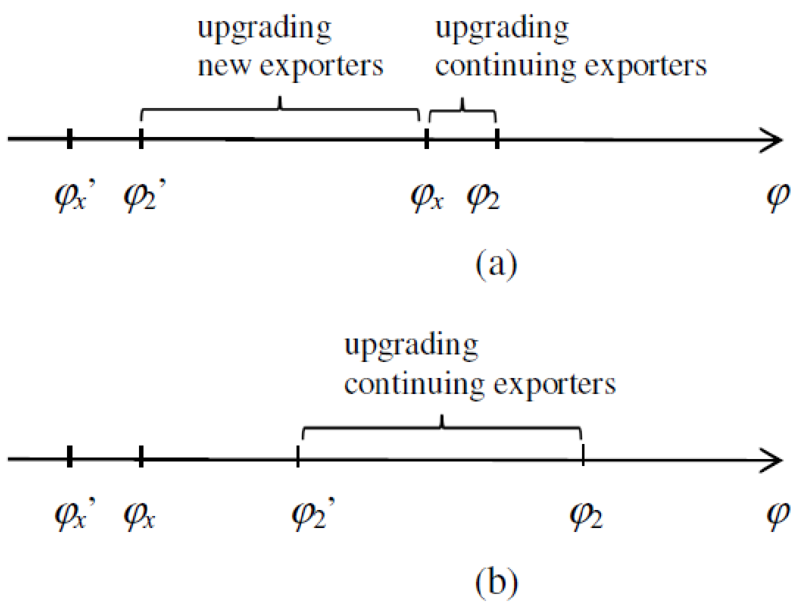

Figure 2: Technology upgrading among new and continuing exporters. *Notation:* Primed thresholds represent the values after trade liberalization. In panel (a), technology upgrading occurs mainly among new exporters. In panel (b), it occurs exclusively among continuing exporters.

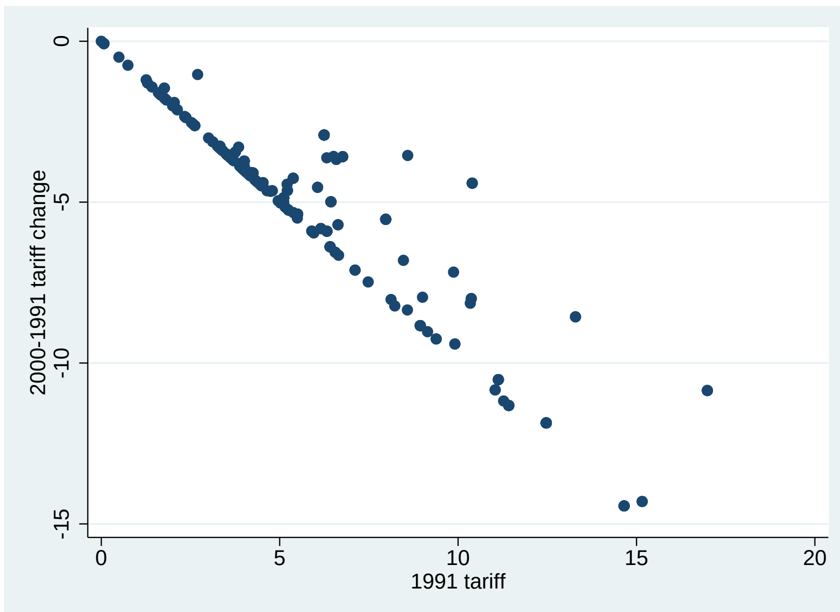

Figure 3: 1991 Industry Tariffs and Subsequent Declines.

A Appendix

Proof of Proposition 1. Using $\pi_t(W,P,\varphi,\delta)$, we can define the cutoffs φ_x^* and φ_2^* as, respectively $\pi_1(W,P,\varphi_x^*,0)=\pi_1(W,P,\varphi_x^*,1)$ and $\pi_1(W,P,\varphi_2^*,1)=\pi_2(W,P,\varphi_2^*,1)$. In addition, the exit cutoff φ_1^* is defined by $\pi_1(W,P,\varphi_1^*,0)=0$. It is convenient to express the first two of these as a function of the third one. Some algebra gives

$$\varphi_x^* = \varphi_1^*\tau(f_x/f_1)^{\frac{1}{\sigma-1}} \tag{16}$$

$$\varphi_2^* = \varphi_1^*\left[\frac{\frac{f_2}{f_1}-1}{\left(1+\tau^{1-\sigma}\right)\left(\lambda^{\sigma-1}-1\right)}\right]^{\frac{1}{\sigma-1}}, \tag{17}$$

where $\lambda=\frac{\gamma\kappa_2}{\kappa_1}\left(\frac{W_{bm}}{W_{bf}}\right)^{\alpha_1(1-\beta_1)-\alpha_2(1-\beta_2)}\left(\frac{W_{wf}}{W_{bf}}\right)^{\alpha_2-\alpha_1}\left(\frac{W_{wm}}{W_{wf}}\right)^{(1-\alpha_1)(1-\varpi_1)-(1-\alpha_2)(1-\varpi_2)}$. These cutoffs are identical to those in Bustos (2011b, p18-19), except for the definition of λ and φ_1^*. This implies that the expression for the relative total revenue $\frac{R_1}{R_2}$ is also identical to hers once λ and φ_1^* are defined appropriately (p20):

$$\frac{R_1}{R_2}=\frac{1}{\lambda^{\sigma-1}(1+\tau^{1-\sigma})}\left\{\left[\frac{\varphi_2^*}{\varphi_1^*}\right]^{k-\sigma+1}-1+\tau^{1-\sigma}\left[\frac{\varphi_2^*}{\varphi_x^*}\right]^{k-\sigma+1}-\tau^{1-\sigma}\right\}.$$

But since under (16) and (17) this expression does not depend on φ_1^*, $\frac{R_1}{R_2}$ only depends on W through λ.

Given (16) and (17), parts (i) and (ii) of the Proposition follow directly from Bustos's (2011b) Proposition 1(e). Proposition 1(b) in Bustos (2011b) implies that $\frac{\partial(R_1/R_2)}{\partial\tau}>0$. Since $\beta_2>\beta_1$, it follows from (7) that $\frac{\partial(W_{bf}/W_{bm})}{\partial\tau}<0$ as stated in part (iii). This result together with (1) implies that firms that do not change their technology after trade liberalization will have a lower relative demand for blue-collar female workers. Therefore, as stated in part (iv), firms switching technology must increase their demand for these workers or else (iii) could not hold.

Proof of Proposition 2. Part (i) follows directly from (9). To see part (ii), use (1) and (2) to write the relative wage paid by a firm using technology t as

$$\frac{\frac{W_{wf}L_{wf}+W_{wm}L_{wm}}{L_{wf}+L_{wm}}}{\frac{W_{bf}L_{bf}+W_{bm}L_{bm}}{L_{bf}+L_{bm}}}=\frac{W_{wf}}{W_{bf}}\frac{\frac{\varpi}{1-\varpi}+1}{\frac{\varpi}{1-\varpi}+\frac{W_{wf}}{W_{wm}}}\frac{\frac{\beta_t}{1-\beta_t}+\frac{W_{bf}}{W_{bm}}}{\frac{\beta_t}{1-\beta_t}+1}.$$

Using (7)-(9) together with the result that $\frac{\partial(R_1/R_2)}{\partial\tau} > 0$ (see Proposition 1), one can show that the derivative of this expression with respect to τ is proportional to the expression in the Proposition. Note that the condition can be satisfied because $\alpha_1 > \alpha_2$.