When Stolper-Samuelson Does Not Apply:  
International Trade and Female Labor*

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Abstract

Whenever a country specializes on industries that use female labor intensively, its female labor force participation should increase. This intuition, which bases on the Stolper-Samuleson Theorem, may fail in a three-factor, two-good model. We develop a model where capital, male and female work are distinct factors of production. We follow an established assumption and postulate that capital accumulation closes the gender wage gap. In this setup, the Stolper-Samuleson based intuition fails necessarily: female labor shares drop in countries that specialize on sectors intensive in female labor, and vice versa. In an empirical part, we use a period of trade liberalization between the U.S. and Mexico to assess the impact of trade on female labor shares at the U.S. state level. To establish causality, bilateral trade between U.S. states and Mexico are instrumented by distance. The tests confirm our theory: exposure to trade with Mexico has increased the gender wage gap and decreased female labor shares in the U.S.

Keywords: International Trade, Factor Prices, Gender Wage Gap, Female Labor.

JEL Classifications: F10, F16, J16, J31.

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1 Introduction

International trade affects relative factor prices. This simple rule applies in particular to male and female wages. More precisely, economic intuition based on the well-known Stolper-Samuleson Theorem suggests that the gender wage gap shrinks in countries, which specialize on sectors that are intensive in female labor.

We show that under standard assumptions this intuition fails to apply. To make our point, we develop a model that builds on two main assumptions. First, competitive firms convert capital, male labor and female labor into two tradable goods using generic constant returns to scale technologies. Second, a rise in the capital stock tends to close the gender wage gap – defined as male over female wages. Under these assumptions, a country’s gender wage gap must increase, whenever the country specializes on sectors intensive in female labor, and vice versa.

The mechanism that drives this seemingly paradoxical result crucially relies on our second assumptions – i.e. capital accumulation closes the gender wage gap – and is best explained in two steps. First, accumulation of capital promotes production in the capital-intensive sector. Therefore, the factor (other than capital), which is used intensively in the capital-intensive sector, experiences an increase in marginal productivity and hence in its factor price. The latter factor must be female labor for this price effect to comply with our second assumption.

As a second step, observe that our second assumption requires a relatively strong complementarity between capital and female labor. Now, an economy that specializes in the capital-intensive sector experiences a contraction of the sector intensive in male labor. Consequently, over-proportionally many male workers migrate to the expanding sector. This inflow of labor into the expanding sector depresses its capital-labor ratio and, given the complementarity between capital and female labor, the returns to female labor decline and the gender wage gap widens.

Finally, given that female labor supply is decreasing in the gender wage gap, female labor shares shrink.

It is worth stressing that we impose minimal restrictions on the setup of our analysis. Regarding production technologies, we merely impose constant returns to scales. In order to address the effects of international trade, our framework features two tradable goods;
and capital, female labor and male labor are three distinct factors of production. We consequently deal with the — slightly unconventional — case of a two-good, three-factor model.

On the preference side, we merely assume that household optimization gives rise to female labor supply that decreases in the gender wage gap. Supply of male labor is inelastic. These assumptions are convenient as they eliminate net income effects on female labor shares and allows us to focus on the effects of movements of factor prices. Other than these, we do not make any restrictions.

While our setup is quite general, some specificities of our model require a word of justification. First, we assume that female labor and male labor are imperfect substitutes, which makes them two distinct factors of production. Acemoglu, Autor, and Lyle (2004) have utilized the large positive shock to demand for female labor induced by World War II to assess the substitutability between male and female labor. Their estimated elasticity of substitution ranges between 2.5 and 3.5.

Second, we assume that capital accumulation tends to close the gender wage gap. Doing so, we follow Goldin (1990), who argues that the rapid accumulation of physical capital was responsible for a dramatic increase in the relative wage of women. Indeed, Goldin writes:

The labor market’s rewards for strength, which made up a large fraction of earnings in the nineteenth century, ought to be minimized by the adoption of machinery, and its rewards for brain power ought to be increased (p. 59).

Galor and Weil (1996) build a theory of the demographic transition formalizing this mechanism. Their approach relies on the intrinsic difference of endowments of brains and brawn by male and female individuals and the relatively high complementarity between capital and mental labor.

Finally, we assume that female labor supply reacts positively to a decrease in the gender wage gap. This link between female labor supply and the gender wage gap is very well established. Blau and Kahn (2007) find that the increase in female labor supply during the period 1980–2000 is due to the decline in the gender wage gap. The authors find that

\footnote{This setting comprises models in which household optimization induces women to split their time between non-market activities as child-rearing and formal employment on the labor market. See Galor and Weil (1996).}
“...married women’s real wages increased in both the 1980s and 1990s, and these caused comparable increases in labor supply in each decade, given women’s positively sloped labor supply schedules.” Moreover, the rise of men’s real wages in the 1990s is reported to have added to the slowdown in the growth of women’s labor supply. Other empirical studies find that women’s labor supply exhibits a positive elasticity regarding females’ wages but a negative cross wage elasticity regarding males’ wages (Goldin 1990, Killingsworth 1983, Juhn and Murphy 1997, Blundell and MaCurdy 1999, Devereux 2004).

Thus, having the building blocks of our setup well secured, we claim that our theory is based on accepted and ‘standard’ assumptions.

To advance our understanding whether trade significantly affects female labor force participation and female relative wage, we test our theory using bilateral trade data for the U.S. (corresponding to a rich economy of our model) and Mexico (a poor economy). In view of data limitations, we restrict our empirical examination to the period between 1990 and 2007, for which high-quality data are available. We build our examination on two major data sources. First, from IPUMS-CPS we establish different measures of female labor force participation, hourly wage and a set of covariates. Second, ‘the Origin of Movement’ database administered by WISER provides export data by U.S. state and destination country.

Central to our estimation strategy is the uneven surge in bilateral trade volumes across the 50 U.S. states over the period 1990-2007 (which we label the NAFTA episode). For example, trade with Mexico increased by almost 3.2 percent of total output for Texas, while for New York the increase was 0.1 percent of total output. We exploit this cross-state variation in the exposure to trade with Mexico to examine how trade has impacted female labor force participation and female relative wage at the state level.

We examine the impact of trade on the gender wage gap as well as female employment shares. We need to acknowledge, however, that measured wages are typically affected by a selection bias, which we discuss below. Our empirical exercise therefore emphasizes the impact of the NAFTA episode on female labor force participation in the U.S.

To assess the impact of trade on female labor shares, we define our dependent variable as either female hours worked as a share of total hours worked or, alternatively, as female...
employment as a share of total employment. In order to establish causality, trade shares are instrumented by geographic distance. In our regressions the impact of trade with Mexico on female labor force participation of U.S. states is always negative and highly significant. Our findings thus support the prediction of our theory. The empirical results are robust to the inclusion of a large number of control variables. Moreover, since our theory suggests that international specialization affects female labor force participation while male labor force participation remains constant, we test our empirical model on male and female labor separately and find support to this prediction. Finally, to eliminate the possibility that the estimated effects are driven by the low-skill sectors only, we limit our sample to highly educated individuals. Our empirical findings hold in all of our specifications.

Since our model predicts that female employment is affected by trade via the factor prices, we investigate the impact of the NAFTA episode on the gender wage gap as well. Doing so, we recognize that the empirical trade literature has documented an asymmetric impact of globalization on employment and wages: liberalization of good markets appears to have a sizable effect on employment but a rather small effect on wages. This asymmetry is typically attributed to a selection bias, which blurs the impact of trade on wages as workers with specific characteristics systematically exit the labor market. In particular, when able women selected into the labor market, less able women tend to leave the labor market in response to a negative wage shock. The measured drop in average wages therefore typically underestimates the true decrease. In line with the literature, we find that the impact of trade with Mexico on average female wage in the U.S. is insignificant. However, when correcting for the selection bias by taking the female wages at different percentiles of the full sample, our results reveal a negative impact of trade on female relative wage. While significance levels remain mixed, these results support our prediction that trade with poor countries tends to widen the gender wage gap in rich countries.

The present study connects to various literatures. Our general analytical framework is of the Heckscher-Ohlin type, as discussed in Helpman and Krugman (1985). Various studies have analyzed generalizations of the standard Heckscher-Ohlin framework. Thus, Chang (1979) considers the case of arbitrary numbers of goods and factors. Inoue (1981)

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4Mulligan and Rubinstein (2008) report that mainly able women selected into the labor market in the 1990s.
analyzes the Stolper-Samuleson Theorem under variable returns to scale. We know from these studies that the Stolper-Samuelson Theorem does not necessarily generalize to such settings. Our own model is closest to the one in Jones and Easton (1983), who investigate effects of good price changes in a two-good, three-factor model. The authors show that in such a setting and under rather technical conditions, an expansion of a sector may actually imply a decrease in the price of its most intensively used factor. In particular, the sign of the movement of relative factor prices depends on factor intensities as well as on the elasticities of factor demand. We add to this literature by showing that under a standard condition – our second assumption above – the factor shares and demand elasticities automatically fulfill the conditions that imply our seemingly paradoxical result concerning female labor shares. In this way, we substitute a set of technical assumptions in Jones and Easton (1983) that involve factor shares and elasticities with a simple, well-known and economically meaningful assumption.

Notwithstanding its theoretical beauty, the Heckscher-Ohlin model has been under attack for some time because of its empirical performance. Starting with Trefler (1995), serious doubts have been cast on the predictive power and relevance of the pure Heckscher-Ohlin theory. The harsh rejection, however, has been mitigated in later studies, e.g. by Debaere (2003) and Schott (2003). The latter study, in particular, has shown that, while factor-proportions specialization is rejected across products, it is consistent with specialization within products. These recent findings underscore that the Heckscher-Ohlin framework does, after all, have the potential to address economic questions empirically.

An extensive number of studies is concerned with the link between international trade and labor markets (Davis 1998, Wacziarg and Wallack 2004, Helpman and Itskhoki 2007, Saint-Paul 1997, Cunat and Melitz 2007). Liu and Trefler (2008) estimate negative but very small effects of outsourcing services to China and India on earnings. In the same line, Ebenstein, Harrison, McMillan, and Phillips (2011) report that offshoring to low wage countries is associated with employment declines in the U.S. Finally, Galor and Mountford (2008) examine the impact of international trade on skill acquisition.

A huge body of literature has focused on the source of the decline in the gender wage gap. Welch (2000), Gosling (2003), Black and Spitz-Oener (2010) and Pitt, Rosenzweig, and Hassan (2011) find that the change in the price of the tasks performed by female labor
are the source of the difference in earnings among the genders. While Welch (2000) and Gosling (2003) focus on the reduction in the value of physical power, Black and Spitz-Oener (2010) address the relative increases in the value of non-routine analytic tasks and non-routine interactive tasks, for which women have relative advantages and Pitt, Rosenzweig, and Hassan (2011) focus on the contribution of health to men’s and women’s schooling and earnings. Mulligan and Rubinstein (2008) attribute the reduction in the gender wage gap from the 1970s to the 1990s to the change in the sign of the selection bias of women in the labor market. The link between trade and the gender wage gap, however, is understudied. One of few exceptions is Becker (1971), who argues that trade increases competition among firms and thus reduces costly discrimination and closes the gender wage gap. Our approach, which takes female and male labor very general, operates in perfectly competitive goods and factor markets through differential demand on male and female labor\footnote{In a growth model, Sauré and Zoabi (2011) focus on primary attributes in modeling female and male labor and show that international trades accelerates economic growth in the capital scarce economy more than the capital abundant economy and, thus, international trade spurs convergence.}. Finally, our theoretical predictions and empirical results are consistent with Blau and Kahn (2007), who not only estimate upwards sloping supply of women’s labor but find, moreover, that the slowing of the increase in married women’s labor supply during the 1990s could be explained by the growth in husbands real wages.

The rest of the paper is organized as follows. Section 2 formalizes our argument, section 3 provides an empirical evidence and section 4 presents some concluding remarks.

2 The Model

We aim to assess the effects of trade liberalization and international specialization. Since we are interested in domestic effects based on factor price changes that can ultimately be traced down to changes in good prices, it is sufficient to employ the framework of a small open economy.

2.1 The Setup

With regard to the framework of our model we try to be general. On the preference side we assume that female labor supply is a decreasing function of the gender wage gap, while
supply of male labor is inelastic. Regarding production technologies, we merely assume constant returns to scales in two tradable sectors. Moreover, female labor, male labor and capital are distinct factors of production. We thus deal with the – slightly unconventional – case of a two-good, three-factor model. This generality on the modeling framework requires that we adopt an open economy framework and formulate our results in terms of exogenous changes in good prices.

2.1.1 Production

Firms transform three different factors $K$, $M$ and $L$ into two distinct consumption goods $Q_1$ and $Q_2$, using the technologies

$$Q_i = F_i(K, M, L) \quad i = 1, 2.$$  \hspace{1cm} (1)

The functions $F^i$ exhibit constant returns to scale, i.e., they are homogeneous of degree one. We assume that the functions $F^i$ are twice continuously differentiable and satisfy

$$F^i_X > 0; \quad F^i_{XY} \geq 0 \quad \text{for} \ X \neq Y; \quad F^i_{XX} < 0$$  \hspace{1cm} (2)

where subscripts stand for partial derivatives and $X, Y \in \{K, M, L\}$. Finally, the usual Inada conditions are assumed to hold.

Sectors differ in their demand for $M$-type labor relative to $L$-type labor. Without loss of generality the first sector is relatively more intensive in $M$, i.e.

$$M_1/\bar{M} > L_1/\bar{L}$$  \hspace{1cm} (3)

holds under firm optimization, provided that $Q_1, Q_2 > 0$ is satisfied.

2.1.2 Factors

The variable $K$ stands for physical capital. For $M$ and $L$ different interpretations are possible. First, $M$ and $L$ may stand for female and male labor, respectively. In this case, under positive output in both sectors,

$$p_1F^1_L = p_2F^2_L \quad \text{and} \quad p_1F^1_M = p_2F^2_M$$  \hspace{1cm} (4)

must hold, as the Inada conditions imply positive employment of all factors in all industries.
Alternatively, the factor $M$ may stand for "brain" or mental inputs, while $L$ stands for "brawn" or raw labor. Male and female workers are endowed with these two distinct types of factors at different proportions. We can think of male workers being endowed with one unit of $M$ and one unit of $L$, while female workers owe one unit of $M$ but $\beta < 1$ units of physical labor only. In this case, the contribution of mental labor rewards are relatively higher for female than for male workers. Whenever interior solutions prevail (workers of both genders are employed in both sectors) wage equalization requires $p_1 \left( F^1_L + F^1_M \right) = p_2 \left( F^2_L + F^2_M \right)$ and $p_1 \left( F^1_M + \beta F^1_M \right) = p_2 \left( F^2_M + \beta F^2_M \right)$, which constitutes a system equivalent to (4). We will focus on interior solutions, so that both interpretations of $M$ and $L$ are, in terms of factor allocation, formally equivalent. Finally, under either of the interpretations of $M$ and $L$, inequality (3) implies that $Q_1$-production is intensive in female labor.

2.1.3 Preferences

Individuals consume the two goods $Q_1$ and $Q_2$ introduced above. Further, we assume that (i) male labor is entirely inelastic and (ii) female labor supply depends on the ratio of male to female wages only.\footnote{This feature may be the outcome of household optimization under home production of a third good. See Galor and Weil (1996) for a corresponding model.} The second assumption implies that we can write supply of female over male working hours as

$$R^s(\omega).$$

The superscript $^s$ indicates supply and $\omega$ stands for the ratio of $M$-factor price over $L$-factor price.

2.2 Inelastic Factor Supply

As a preparatory step to our main results, we consider an economy with inelastic factor supply. Denoting the vector of factor endowments with $\bar{Z} = (K, M; L)^t$, we write $Z = (K_1, M_1, L_1)^t$ for the vector of factors employed in the $Q_1$-sector.

2.2.1 Factor Allocation

Competitive firms maximize their profits. In terms of factor allocation, such maximization is equivalent to the maximization of total revenues (see Mas-Colell, Whinston, and Green).
(1995)):
\[
\max_Z p_1 F^1(Z) + p_2 F^2 (\bar{Z} - Z)
\]
(6)
We assume that the solution to (6) is unique and interior and denoted by \( Z^*(\bar{Z}) \).

Further, we introduce the notation \( w_X \) for the reward of factor \( X \). With this notation, we can formulate the following lemma.

**Lemma 1** Assume prices \( p_i \) are constant, then (2) implies
\[
\frac{d}{d\bar{X}} \ln \left( \frac{w_X}{w_Y} \right) < 0 \quad X, Y = K, L, M \quad Y \neq X
\]
(7)

**Proof.** See Appendix. □

The lemma states that an increase in aggregate supply of one factor decreases its price relative to the price of all other factors.

### 2.2.2 Wage-Raising Capital Accumulation

An important branch of the economics of demography have argued that the accelerating capital accumulation has helped to closed the gender wage gap. Following this literature, we assume that an increase in the capital stock raises the rewards of \( M \)-type labor more than that of \( L \)-type labor, i.e.
\[
\frac{d}{dK} \ln \left( \frac{w_M}{w_L} \right) > 0,
\]
(8)
Referring to the seminal contribution by Goldin (1990), we will refer to this inequality as the “Goldin-Assumption”.

It will prove useful to formulate the relations between equilibrium factor allocation and prices in terms of demand elasticities. Doing so, however, we need to account for the fact that under constant return to scale technologies, the good- and factor-prices determine factor demand uniquely only up to a scaling factor. To regain unique factor demand, we thus consider relative factor demand \( k = K/L \) and \( m = M/L \). The relation between factor allocation and factor prices is then
\[
\begin{pmatrix}
\Delta \hat{w}_K \\
\Delta \hat{w}_M
\end{pmatrix}
= \begin{pmatrix}
\hat{w}_K - \hat{w}_L \\
\hat{w}_M - \hat{w}_L
\end{pmatrix}
= \begin{pmatrix}
\alpha_{kK} & \alpha_{kM} \\
\alpha_{kL} & \alpha_{mL}
\end{pmatrix}
\begin{pmatrix}
\hat{k} \\
\hat{m}
\end{pmatrix}
\]
(9)
where we have set \( \hat{X} = dX/X \) and \( \alpha_y^X = \left[ d(w_X/w_L) / dy \right] / \left[ (w_X/w_L) / y \right] \).
In the terminology thus defined, the “Goldin-Assumption” \( \text{(8)} \) becomes
\[ \alpha_k^M > 0. \]
Finally, inequality \( \text{(7)} \) applied to \( X = K, M; Y = L \) as well as \( X = L; Y = K, M \) implies
\[ \alpha_X^X < 0 \quad \text{and} \quad -\alpha_k^X - \alpha_m^X > 0 \quad X = K, M. \]
Together, these conditions imply that the determinant of the 2 \( \times \) 2 matrix from \( \text{(9)} \) is positive\(^7\)
\[ D = \alpha_k^K \alpha_m^M - \alpha_m^K \alpha_k^M > 0. \]
We can thus invert the system \( \text{(9)} \), writing
\[
\begin{pmatrix}
\hat{k} \\
\hat{m}
\end{pmatrix} =
\begin{pmatrix}
\sigma_k^k & \sigma_m^k \\
\sigma_k^m & \sigma_m^m
\end{pmatrix}
\begin{pmatrix}
\Delta \hat{w}_K \\
\Delta \hat{w}_M
\end{pmatrix} \quad \text{(10)}
\]
According to Cramer’s rule, \( \sigma_k^k = \alpha_m^M / D, \sigma_m^m = \alpha_k^K / D, \sigma_k^m = -\alpha_m^K / D \) and \( \sigma_m^k = -\alpha_k^M / D \) hold so that the above inequalities on the \( \alpha_X^y \) are
\[ \sigma_k^m < 0 \quad \text{and} \quad \sigma_y^y < 0 \quad \text{and} \quad |\sigma_y^y| > |\sigma_X^y| \quad (Y, X = K, M; \ X \neq Y). \quad \text{(11)} \]
At the same time, \( \sigma_X^y \) is the elasticity of relative demand with respect to the relative factor price, i.e.
\[ \sigma_X^y = \frac{(w_X / w_L)}{y} \frac{dy}{d(w_X / w_L)} \quad X = K, M \quad y = k, m. \quad \text{(12)} \]
Hence the first of the inequalities in \( \text{(11)} \) constitutes the “Goldin-Assumption” \( \text{(8)} \) expressed in terms of factor demand elasticities. In particular, we know that increases in the factor price of capital must decrease the relative demand for \( M \)-type labor.

2.2.3 Capital Intensity

Having stated our main assumption concerning wage-raising capital accumulation, we now turn to the first important result, which concerns relative capital intensities of the two sectors.

**Proposition 1** If \( \text{(2)}, \text{(3)} \) and \( \text{(8)} \) hold and \( Z^*(\bar{Z}) \), is interior, then
\[ K_1 / \bar{K} > M_1 / \bar{M} \quad \text{(13)} \]
\(^7\)If \( \alpha_m^K < 0 \) this statement is true by the inequalities on the \( \alpha_X^y \) above. If \( \alpha_m^K > 0 \), instead, use
\[ -\alpha_k^X - \alpha_m^X > 0 \] to verify \( \alpha_k^M \alpha_m^M - \alpha_m^K \alpha_k^M > -\alpha_m^K \alpha_m^M - \alpha_m^K \alpha_k^M = \alpha_m^K (-\alpha_m^M + \alpha_k^M) > 0. \]
Proof. As the solution to (6) is interior, we can write \( w_X = F_X^1 (X = K, L, M) \). Observe that the uniqueness of the solution to (6), together with HD1 of \( F_i \), implies linear independence of \( Z^* \) and \( \bar{Z} - Z^* \). Further, at constant \( p_i \), an increase of the vector \( \bar{Z} \) in the directions \( Z^* \) or \( \bar{Z} - Z^* \) leaves factor prices unchanged. Thus, factor prices are constant under a marginal change of \( \bar{Z} \) in the direction \( \xi = Z^* - \gamma (\bar{Z} - Z^*) \) for all \( \gamma \in \mathbb{R} \). The particular choice \( \gamma = M_1 / (\bar{M} - M_1) \) implies \( \xi = (\xi_1, 0, \xi_3) \). Hence,

\[
\left( \xi_1 \frac{d}{dK} + \xi_3 \frac{d}{dL} \right) \ln \left( \frac{F_{1M}^1 (z^*)}{F_{1L}^1 (z^*)} \right) = 0
\]

holds so that, by (8) and (7) with \( X \) and \( Y \), \( \xi_1 \) and \( \xi_2 \) have opposite sign. By (3) we have \( \bar{M} / \bar{M} > L_1 / L \) and thus

\[
\xi_3 = L_1 - (\bar{L} - L_1)M_1 / (\bar{M} - M_1) < 0.
\]

Therefore, \( \xi_1 = K_1 - (\bar{K} - K_1)M_1 / (\bar{M} - M_1) > 0 \) holds, implying (13). \( \blacksquare \)

The proposition shows that \( Q_1 \)-production is relatively more \( K \)-intensive than \( M \)-intensive. Together with (3) we then have

\[
\frac{K_1}{K - K_1} > \frac{M_1}{M - M_1} > \frac{L_1}{L - L_1}
\]

Interestingly, in a two-sector world Goldin’s statement implies that the sector, which is intensive in female labor (relative to male labor), is necessarily even more intensive in capital. An intuition for this result obtains from the following considerations. Assume that \( X_2 \)-production were \( K \)-intensive, violating (13), while (3) still implied that \( X_1 \)-production is \( M \)-intensive. Under these assumptions, increases in the capital stock would spur production of the \( X_2 \)-sector (presuming that an Rybczynski-like effect operates). In terms of factor prices, this advantage to the \( X_2 \)-sector should benefit mainly the factor it uses most intensively – i.e., male labor. But this is ruled out by assumption (8). – It must be stressed that this explanation provides not more than an intuition. As shown further below, simple arguments relating factor intensities to movement of relative factor prices are not admissible. Instead, an important role is played by factor demand elasticities.

2.2.4 Price Changes

To analyze the effects of changes in goods prices, we adapt and extend the results from Jones and Easton (1983) to our current setting. For the time being, we keep the assumption

\[
\frac{K_1}{K - K_1} > \frac{M_1}{M - M_1} > \frac{L_1}{L - L_1}
\]
that factors are inelastically supplied. We start by introducing the notation \( a_{Xj} \) for the (equilibrium) input requirement of factor \( X = K, M, L \) to produce one unit of good \( j = 1, 2 \). With this notation the inequalities (14) become

\[
\frac{a_{K1}}{a_{K2}} > \frac{a_{M1}}{a_{M2}} > \frac{a_{L1}}{a_{L2}}
\]

Multiplying each \( a_{Xj} \) by the according factor price \( w_X \) and dividing by the respective good prices, \( p_j \), leads to the expenditure share of factor \( X \) in sector \( j \), which we denote by \( \theta_{Xj} = w_X a_{Xj}/p_j \). Hence, the condition above is equivalent to

\[
\frac{\theta_{K1}}{\theta_{K2}} > \frac{\theta_{M1}}{\theta_{M2}} > \frac{\theta_{L1}}{\theta_{L2}}
\]

(15)

In a competitive economy with constant returns to scale

\[
\sum_X a_{Xj}w_X = p_j \quad j = 1, 2
\]

(16)

is satisfied as long as both goods are produced in positive quantities.

Being interested in a change in relative price changes we next consider a marginal increase in \( p_j \) \( (j = 1, 2) \). Differentiating expression on the left of (16) with respect to \( p_i \), we apply the envelope theorem to cost minimization (taking partial derivatives of \( w_X \) only), which leads to

\[
\sum_X \theta_{Xj}\hat{w}_X = \delta_{ij} \quad j = 1, 2
\]

(17)

where \( \delta_{ii} = 1, \delta_{ij} = 0 \ (j \neq i) \) and \( \hat{y} = (dy/dp_1)p_1/y \) as defined above.

Finally, the second line of the system (10) reads

\[
\sigma^m_K (\hat{w}_K - \hat{w}_L) + \sigma^m_M (\hat{w}_M - \hat{w}_L) = \hat{m}.
\]

(18)

Combining now (17) and (18) leads to

\[
\begin{pmatrix}
\theta_{K1} & \theta_{M1} & \theta_{L1} \\
\theta_{K2} & \theta_{M2} & \theta_{L2} \\
\sigma^m_K & \sigma^m_M & -\sigma^m_K - \sigma^m_M
\end{pmatrix}
\begin{pmatrix}
\hat{w}_K \\
\hat{w}_M \\
\hat{w}_L
\end{pmatrix}
= 
\begin{pmatrix}
\hat{p}_1 \\
\hat{p}_2 \\
\hat{m}
\end{pmatrix}
\]

(19)

where we have used \( \sum_X \sigma^m_X = 0 \).

We will now analyze a one percentage increase in \( p_1 \) at constant factor supply. To this aim, consider the exogenous change \( (\hat{p}_1, \hat{p}_2, \hat{m})^t = (1, 0, 0)^t \) in (19). To solve this specific
system, denote the determinant of the $3 \times 3$ matrix by $\Delta$ and use Cramer’s Rule to compute (setting $\sigma^k = -\sigma^K - \sigma_M^k$)

$$
\hat{w}_K = \Delta^{-1} \det \begin{pmatrix}
1 & \theta_{M1} & \theta_{L1} \\
0 & \theta_{M2} & \theta_{L2} \\
0 & \sigma^K_{M} & \sigma^K_{L}
\end{pmatrix}
= \Delta^{-1} [\sigma^K_L \theta_{M2} - \sigma^K_M \theta_{L2}]
$$

$$
\hat{w}_M = \Delta^{-1} \det \begin{pmatrix}
\theta_{K1} & 1 & \theta_{L1} \\
\theta_{K2} & 0 & \theta_{L2} \\
\sigma^K_{K} & 0 & \sigma^K_{L}
\end{pmatrix}
= -\Delta^{-1} [\sigma^K_L \theta_{K2} - \sigma^K_K \theta_{L2}]
$$

$$
\hat{w}_L = \Delta^{-1} \det \begin{pmatrix}
\theta_{K1} & \theta_{M1} & 1 \\
\theta_{K2} & \theta_{M2} & 0 \\
\sigma^K_{K} & \sigma^K_{M} & 0
\end{pmatrix}
= \Delta^{-1} [\sigma^K_M \theta_{K2} - \sigma^K_K \theta_{M2}]
$$

Using $\sum_X \theta_{Xj} = 1$ and $\sum_X \sigma^K_X = 0$ leads to

$$
\hat{w}_K = -\Delta^{-1} \left[ \sigma^K_K \theta_{M2} + \sigma^K_M (1 - \theta_{K2}) \right] \quad (20)
$$

$$
\hat{w}_M = \Delta^{-1} \left[ \sigma^K_M \theta_{K2} + \sigma^K_K (1 - \theta_{M2}) \right] \quad (21)
$$

$$
\hat{w}_L = \Delta^{-1} \left[ \sigma^K_M \theta_{K2} - \sigma^K_K \theta_{M2} \right]
$$

Employ again $\sum_X \theta_{Xj} = 1$ and $\sum_X \sigma^K_X = 0$ to compute the determinant $\Delta$:

$$
\Delta = \det \begin{pmatrix}
\theta_{K1} & 1 & \theta_{L1} \\
\theta_{K2} & 1 & \theta_{L2} \\
\sigma^K_{K} & 0 & -(\sigma^K_K + \sigma^K_M)
\end{pmatrix}
= (\theta_{L2} - \theta_{L1}) \sigma^K_K - (\theta_{K1} - \theta_{K2}) (\sigma^K_K + \sigma^K_M) \quad (22)
$$

Combining (21) and (22) leads to

$$
\frac{d}{dp_1} \ln \left( \frac{w_M}{w_L} \right) = \frac{\sigma^K_M}{(\theta_{M1} - \theta_{M2}) \sigma^K_K - (\theta_{K1} - \theta_{K2}) \sigma^K_M}
$$

This identity implies that the wage gap $w_M/w_L$ is decreasing in $p_1$ if and only if the expression on the right is negative. Now, using (15) together with $\sum_X \theta_{Xj} = 1$, implies $\theta_{K1} > \theta_{K2}$. Since further $\sigma^K_M < 0$ holds by (11), we can state that a necessary and sufficient condition for the expression above to be negative is

$$
\frac{\theta_{M1} - \theta_{M2}}{\theta_{K1} - \theta_{K2}} \leq \frac{\sigma^K_M}{\sigma^K_K}
$$

Finally, the condition formulated in (11) imply that the expression on the right exceeds one, while the expression on the left falls short of unity, by (15). This proves the following statement.
Proposition 2: If \( (8) \) holds, then
\[
\frac{d}{dp_1} \ln \left( \frac{w_M}{w_L} \right) < 0
\]

The proposition shows that, under the “Goldin-Assumption” \( (8) \) the intuition based on the Stolper-Samuelson effect of a two-good two-factor economies never generalizes to \( M \)- and \( L \)-type labor in the current setting. Any price increase of the good whose production uses \( M \)-type labor more intensively than \( L \)-type labor, decreases the reward for \( M \)-type labor relative to that of \( L \)-type labor.

The key condition, of course, is the “Goldin-Assumption”. In absence of it, the usual intuition concerning the interplay of factor intensities, international specialization and relative factor prices is likely to go through. Thus, Jones and Easton (1983) show that in order for the usual intuition to fail, a combination of rather technical assumptions needs to be satisfied. With Proposition 2 we have refined the findings of this earlier work by formulating an established, simple and handy condition with a clear economic meaning, under which the counter-intuitive effects operate.
2.3 Elastic $M$-Supply

It is now quick to translate these findings to a framework with elastic $M$-supply. Depending on our interpretation of the factors $M$ and $L$, the ratio of female wage over male wage equals

$$\frac{F^1_M}{F^1_L} \quad \text{or} \quad \frac{F^1_M/F^1_L}{F^1_M/F^1_L + \beta}$$

Therefore, the supply of female labor over male labor $R_s$ from (5) is a function of relative factor prices $\omega = \frac{w_M}{w_L} = \frac{F^i_M}{F^i_L}$. As we have assumed above, the function $R_s(\omega)$ is increasing (see (5) in subsection 2.1.3).

Turning now to the demand for $M$-type labor, we know recall that the factors $K$ and $L$ are in inelastic supply. Thus, applying (7), we infer that an increase in $\bar{M}$ lowers the ratio of factor prices $\omega = \frac{w_M}{w_L}$. Inverting this relation implies that demand for $\bar{M}$, denoted by $R_d(\omega)$, is a decreasing function of $\omega$.

The functions $R_s$ and $R_d$ are plotted in Figure 1 as solid lines – $R_s$ as an increasing function and $R_d$ as a decreasing function of $\omega$. The figure also depicts the effects of an increase in $p_1$, which, by Proposition 2, decreases the ratio $w_M/w_L$ for any given level of $\bar{M}$ ($\bar{K}$ and $\bar{L}$ are constant anyway). This means that the increase of $p_1$ shifts the $R_d$-schedule to the left. Since the $R_s$-schedule is unaffected by the price change, the equilibrium employment of $M$ drops from $M^*$ to $M^{**}$.

2.4 International Specialization

Up to this stage, we have considered exogenous price changes. We refrain from solving the general equilibrium of a world economy of many countries. Nevertheless, we will analyze the patterns of specialization that arise in equilibrium and their effect on the female labor force participation.

To this aim, assume that the world economy consists of a collection of the type described above. We still are very general on the technologies and almost entirely agnostic about the preferences over consumption goods. Thus, we assume that each country faces a set of production technologies (1) with which to produce the two consumption goods and individuals have preferences that give rise to $M$-type labor supply (5). We specifically do not require technologies or preferences to be identical across countries. This implies that international specialization may be driven by differences in technologies (1), in the
per-household capital stocks, in demand for the consumption goods, or by a combination of all.

There are only two key assumptions we make. First, we assume that the “Goldin Assumption” holds for each of the countries. Second, a drop in the relative price of a good is associated with a drop in this country’s excess supply of the relevant good. Put differently, the Marshall-Lerner stability conditions are met by assumption. Now, we say that a country intensifies specialization in good $X_i$ if and only if its excess supply of $X_i$ rises. With this terminology, and under the conditions stated above, we can apply Proposition 2 to formulate the following Lemma.

**Lemma 2** Female labor shares drop in countries that intensify specialization on sectors intensive in female labor.

Notice that it is irrelevant whether the shift in excess supply and the associated price change originates from a removal of trade barriers, from demand shifts or from (foreign) technological change. Since all effects of trade ultimately operate through a shift in good prices, our result is independent from the actual source of the international pattern of specialization. In this sense, we claim that our finding, which runs counter to the well-established intuition derived from the Stolper-Samuelson Theorem, is very general.

### 3 Empirical Evidence

Our theory predicts an asymmetric impact of trade liberalization on the labor market of economies that specialize in sectors intensive in female or male labor: while trade decreases female labor force participation and female relative wage in the former, it tends to increase both of these measures in the latter. The generality of our result allows for various motives of international specialization. Given our Heckscher-Ohlin framework, however, a natural starting point for our analysis is the look at trade liberalization between two countries: a capital rich one with strong integration of women in the labor market and a capital poor one with low levels of female labor participation. We therefore choose to test our theory by looking at trade between the U.S. and Mexico. These two countries paradigmatic for a
We will exploit the removal of trade barriers between the U.S. and Mexico during the period 1990 to 2007. This period will simply be labeled the "NAFTA episode" in the following.

Figure 2: U.S. Trade Share – Imports plus Exports over GDP – with Mexico (red line, right scale) and Mexico’s Share of U.S. Trade Volumes (blue line, left scale). Source: (1) Nominal GDP: are from Heston, Summers, and Aten (2006) and (2) US imports from and export to Mexico are from Feenstra, Lipsey, Deng, Ma, and Mo (2005) for the period 1962 - 2000 and from United States International Trade Commission for the period 2001 - 2008

The choice of the NAFTA episode has a number of virtues. First, U.S.-Mexican trade experienced a substantial growth during that period: U.S. trade with Mexico as a share of U.S. GDP increased by more than a factor of 3 between 1990 and 2007, while Mexico’s share in U.S. total trade rose by more than a factor of 2 (Figure 2). Via this substantial increase of bilateral trade volumes we hope to identify a sizable impact of trade on labor.

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9Capital stocks per worker can be calculated from real investment data as in PWT6.2. At depreciation rates between .01 and .1, the relative capital stock of the U.S. in 2003 exceeds the one of Mexico by a factor of four. Consistent with our theory, the female labor share in the U.S. ranged from 43.1 to 46.3 between 1985 and 2006 while the according range for Mexico is 29.4 to 35.3 (United Nations Statistics Division).

10This label is misleading to the extent that not all of the increase in US-Mexican trade is attributed to tariff reductions of NAFTA. In fact, Krueger (1999) puts forward that Mexico’s unilateral tariff reduction in the late 1980s and its abandoning of the exchange rate peg explains the larger part of the increase in trade volumes. For the purpose of our test, however, this observation is of minor importance. We are only concerned about identifying an episode of substantial increase in trade volumes.
markets. Second, the choice of the NAFTA episode allows us to take advantage of the high quality of U.S. trade and labor market data. In particular, we can exploit exposure to trade with Mexico on a U.S. state level. Finally, due to the specific geographical constellation, U.S. trade with Mexico is particularly uneven across U.S. states, which allows us to use distance as a powerful instrument for a change in trade volumes and thus establish causality running from change in trade to change in female labor share and female relative wage.

3.1 Data

We rely on three different data sources. The first one we use is the March Current Population Survey conducted by the Integrated Public Use Microdata Series (IPUMS-CPS). From IPUMS-CPS we take the variables age, sex, marital status, population status (to distinguish between civilian or Armed Forces), nativity (to identify immigrants), location (state), Hispanic origin (to identify Mexicans), educational attainment, employment status (to compute the formal employment share) weeks worked, usual hours worked (to compute total hours worked) and wage and salary income (to compute hourly wage). Table 1 provides descriptive statistics for female and male labor for the years 1990/91 and 2006/07. Two observations can be drawn from Table 1 during the NAFTA episode: first, while female labor force participation has increased, male labor force participation has decreased and, second, the hourly wage for both genders has increased during the same period. The second database we use is the “Origin of Movement” administered by WISER, which covers export data by state and destination country from 1988 onward. These data are disaggregated by good categories (SIC from 1988 to 2000; NAICS from 1997 onward). The third database we use is the Bureau of Economic Analysis for GDP data on the state level.

3.2 Female labor force participation

3.2.1 The Empirical Model

In our empirical exercise we concentrate on one side of our theory and aim at identifying the effect of trade on the U.S. labor market (the capital rich economy). More precisely,

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we exploit the variation of U.S.-Mexican trade across different U.S. states to identify the
differential impact of trade on female labor shares and female relative wage across states.\footnote{The focus on U.S. states as economic entities may seem problematic since state borders are not relevant restrictions for the labor. This drawback, however, implies that inter-state labor migration can eliminate differences in the wage gap and female labor force participation across states, which tends to eliminate the differential effects of trade across states. Thus, no differential effect of trade on female labor shares across states can be expected as long as the U.S. labor market works frictionless. We nevertheless expect to capture labor markets effects to the extent that frictions of labor movement related to geographical distance impede a full equalization of factor prices across U.S. states.}

As discussed in the introduction, previous empirical literature has revealed that the
impact of trade liberalization on wages is smaller than the impact on employment and that
the latter is of marginal magnitude. Thus, we begin by examining whether NAFTA had
any impact on female employment and subsequently move to its impact on wages.

According to our theory, a higher exposure to trade with Mexico induces lower female
labor force participation in the different U.S. states. Put differently, our theory suggests
that, other things equal, a state that is exposed to a larger expansion in trade will experience
a higher reduction in female labor force participation.

Analyzing this relation on the state level, our reduced form model takes the following form

\[
\Delta y_s = \alpha + \beta \Delta Trade_s + X'_s \gamma + u_s
\]  

(24)

where for any variable $z_s$ the $s$ indicates the different U.S. states and $\Delta$ indicates the change
over time: before and after NAFTA. The dependent variable $y_s$ is the female labor share,
$Trade_s$ is trade volume per output. We control for a vector of covariates $X'_s$ chosen by
economic intuition but unrelated to our theoretical model. Our initial period is 1990-1,
while the end period is 2006-7.\footnote{This time window is determined by availability of trade data. The data set includes entries for the
years 1988/89 but these are of minor quality.} Our theory predicts that the estimate of $\beta$ in (24) is
negative.

We first run an OLS regression of the form described in (24). However, labor market
conditions in the U.S., reflected by higher shares of female labor can constitute a form
of comparative advantage and thus drive trade volumes. This endogeneity biases our OLS
estimates and leaves us with the need to instrument in order to establish the desired
causality.
We slightly modify the gravity equation of the trade literature and instrument $\delta Trade_s$ by distance to Mexico. Thus, our first stage regression is:

$$\Delta Trade_s = \mu + \theta d_s + X'_s \rho + \nu_s$$  \hspace{1cm} (25)$$

where $d_s$ is distance of state $s$ to Mexico.

Figure 3: Change in Trade with Mexico by State (1990-2007). left Panel: all states; right panel: excluding Alaska, Hawaii and Texas.

Figure 3 illustrates that distance is strongly correlated with the increase in trade share, satisfying a first necessary condition for being a valid instrument.

It still may be the case that our instrument distance to Mexico has a direct effect on female labor force participation or is correlated with other relevant variables that have an effect on female labor force participation. Possible examples are development, culture or religiosity, which are typically correlated with latitude. However, by using first difference we difference out state fixed effect. As an additional test for the validity of our instrument we conduct the following falsification test. Using data from the pre-NAFTA period we regress a reduced form model of the change in female labor force participation on distance. We find supportive evidence of our presumption that only during the NAFTA period there

\[ \text{slope} = -2.13 \hspace{1cm} \text{t-statistic} = -3.92 \]

\[ \text{slope} = -3 \hspace{1cm} \text{t-statistic} = -3.75 \]

\[ 16 \text{More precisely, we regress trade volume as a percentage of GSP on spherical distance of U.S. state-captials to Mexico City, while the standard gravity equation estimates the log of bilateral trade volume on the log of GDP, spherical distance and other variables. Our justification is the fit of the data.} \]
is a positive impact of distance on the change in female labor force participation, which suggests that the exclusion restriction is likely to hold.\footnote{17}

### 3.2.2 Control Variables

To control for differential business cycle effects across states we include the change in log per capita “Gross State Product” (GSP) and unemployment rate. We also control for the change in average education level for females, which is positively correlated with female labor share.\footnote{18} Further, we include the share of Mexican immigrants, which might either depress female labor participation – \textit{e.g.} due to cultural differences reducing gender labor market participation,\footnote{19} – or else increase female labor participation – \textit{e.g.} by increasing supply of nannies and private child-care. We have no strong prior on the sign of this latter control variable.

The secular trend towards higher female labor force participation together with the fact that it is naturally bounded from above implies that female labor force participation converges across states. Hence, the initial level of female labor share is highly correlated with the change in female labor force participation. To account for this convergence effect, we include initial level of female labor force participation in the controls when estimating (24). A problem with this control variable, however, is that it is correlated with the error term in (24), wherefore we instrument it with lagged female labor participation (values from 1980/81).

### 3.2.3 Regression Results

For our baseline specification we define female labor participation as the share of hours worked by females. Taking this share is not a strict necessity but it eliminates labor market shocks that are common to both sexes. In all our specifications labor force is defined as the total of individuals aged between 16 and 65, excluding members of the Armed Forces.

\footnote{17}{Exact details about our falsification test are explained in the Appendix and its results are reported in Table 7}
\footnote{18}{We define two categories of education. First, educated individuals who have at least some college and for whom we assign a weight of 1. Second, uneducated individuals who are at most high school graduates and for whom we assign a weight of 0. The education level of a state is defined as the average of individual weights.}
\footnote{19}{On a national level, this concern seems unsubstantiated: national averages of female hours worked as percentage of male hours worked of Mexicans exceed the according numbers of the full sample by 0.5% to 1.9% between 1990 and 2007.}
We further define exposure to trade as twice the state exports to Mexico over GSP. The restriction to export is due to the fact that import data per state are not available. Distance is spherical distance from state-capitals to Mexico City.

Table 2 reports the results of our baseline regression. Column 1 reports a simple OLS regression of our dependent variable: change in female labor share on an initial level of female labor share, which we take to be the average of 1980 and 1981 and the change in trade with Mexico. As discussed earlier, we are not surprised by insignificant coefficient of our main variable, \( \Delta \text{Trade with Mexico} \), since this OLS regression suffers from a bias due to endogeneity problems. Insignificance of the coefficient merely indicates that there might be other channels, which cancel out the negative impact of trade on female labor shares. One possible channel is a reversed causality that blurs the true exogenous impact of trade on female labor shares. This hypothesis is consistent with our theory as the relatively high female labor force participation in the U.S. constitutes a form of comparative advantage and, thus, spurs trade volumes.

To avoid this endogeneity and to identify the causal relation running from change in trade to female labor shares, we focus on the remaining five columns that summarize IV estimates, where the change in trade is instrumented by distance. Column 2 reports estimates without controls, Column 3 includes average female labor share of 1990 and 1991, which is instrumented by the average values of 1980 and 1981; Column 4 includes the differences of log per capita GSP and unemployment share; Column 5 includes differences in female education share and Column 6 includes change in Mexican immigration share.

The coefficient of our interest is the one on change in trade with Mexico (\( \beta \)). All of its estimates have the expected negative sign and most of them are significant on the one percent confidence level. Column 3, indicates that a one percent increase in trade share with Mexico (as experienced by Arizona) decreases the female relative to male labor share by around 1.5 percent. The coefficient on the initial level of female labor share is negative and significant, as generally implied by convergence.

\[ ^{20} \text{We assume that import equalizes export in order to reveal, quantitatively, a more realistic coefficient of trade on female labor share.} \]

\[ ^{21} \text{Table 2 shows that the OLS estimate is larger than IV estimate. One possible interpretation from this difference, which is consistent with our theory is that higher female labor force participation induces a higher relative advantage in the capital intensive sector which implies higher international specialization and trade.} \]
3.2.4 Robustness

We next conduct some robustness check for the results obtained in the baseline regression (Column 3 in Table 2). First, we exclude Texas as well as Alaska and Hawaii from the sample since these states appear to be outliers in terms of distance (see Figure 3), and hence in predicted trade shares. Table 3 summarizes the corresponding results in the first three columns. The exclusions do not affect the general picture: the impact of trade share with Mexico remains negative and significant at the 1% confidence level (5% in Column 3).

We are also concerned about our definition of trade shares, since Cassey (2009) reports that export data exhibit systematic differences between “origin of movement definition” and “origin of production.” Since these errors are substantial in the agricultural and mining sectors only, we replace total export over GSP per state by the according manufacturing export percentages. Column 4 in Table 3 shows that our concerns are unsubstantiated: the estimates are still significant at the 1% level and estimated magnitudes are very similar.

In trade literature the standard measure for distance is the spherical one (spherical distance between capitals). We check whether our results depend on the choice of distance and replace it by ground distance to the Mexican border (Column 5 in Table 3). Results show that neither the point estimates nor the significance level are affected.

Since our theory rests on the within household optimization, it seems appropriate to restrict our sample to married individuals only. Column 6 in Table 3 shows that the point estimates remains in the same range and only the significance level drops slightly to 5%.

Next we replace the definition of our dependent variable from share of hours to relative employment. This obviously eliminates the important intensive margin of individuals’ labor market participation. Nevertheless, Column 7 in Table 3 shows that the estimates are significant at the 5% level.

Our theory suggests that trade-induced specialization reduces female labor force participation in capital rich country while making male workers merely change sectors. Consequently, we need to check that our results above are driven by changes in female employment only. We do so by investigating the impact of trade on female and male working hours separately. Average female hours per week are 22.77 (standard deviation across states is 1.92) in 1990/1991 and 24.24 (1.84) in 2006/2007. The according numbers for male are 32.92

\[22\text{Ground distance is measured in time and derived from maps.google.com.}\]
While all point estimates of the coefficient on change in trade share with Mexico are negative and significant for females, trade, overall, does not significantly impact male hours: estimates are mostly insignificant, positive and around zero.

Finally, we limit our sample to highly educated individuals for two reasons. First, our theory suggests that female labor force participation drops since it complements capital and part of this complementarity may stem from the complementarity between skill and capital. Second, this limitation eliminates the possibility that our estimated effects stem from composition effects between skilled and unskilled workers. Consistent with our theory, Table 5 shows that all regressions exhibit a negative impact of trade on female labor force participation while such an impact does not prevail for male workers.

### 3.3 Female relative wage

#### 3.3.1 The Empirical Model

Since our mechanism suggests that trade and specialization affect female labor force participation through females’ relative wages, we would like to empirically examine whether U.S. trade with Mexico had the expected impact on the relative wages of U.S. females. Although there is a consensus in the literature that the impact of trade on wages is very weak we would like to see whether higher trade with Mexico has an impact on the relative wage of U.S. females and whether this impact has the expected sign.

According to our theory, a higher exposure to trade with Mexico induces lower female relative wage in the different U.S. states. Put differently, our theory suggests that, other things equal, a state that is subject to higher expansion in trade with Mexico will experience a larger decreases in female relative wage.

Following the specification in (24), we analyze the relative wage on the state level with the following empirical model

\[
\Delta \left( \frac{w_f}{w_m} \right)_s = \alpha' + \beta' \Delta Trade_s + X'_s \gamma' + v_s
\]  

(26)

The dependent variable \( \Delta \left( \frac{w_f}{w_m} \right)_s \) is the change in the relative wage of females in state \( s \).

---

23 Columns 2, 4, 6 and 8 in Table 4 show that using population weight to unravel the impact of change in trade at the individual level does not change neither the magnitudes of our estimates nor their significance.

We keep the same notation of section 3.2. Our theory predicts that the estimate of $\beta'$ in (20) is negative.

We focus on one specification, which corresponds to the one in Column 3 of Table 2. Accordingly, our first stage regression is the same as in (25). We control for the initial level of relative wage and in order to avoid its correlation with the error term in (20), we instrument it with a lagged female relative wage (values from 1980/81).

### 3.3.2 Regression Results

Table 6 reports the results of our regression. Column 1 reports an IV regression of our dependent variable: change in female relative wage on an initial level of female relative wage, which we take to be the average of 1980 and 1981 and the change in trade with Mexico. However, as described in the introduction, Mulligan and Rubinstein (2008) find that the selection of women into the labor market during the 1990s was positive, which implies that mainly the less able women, i.e. those with the lower wages, tend to leave the labor market due to the negative shock to wages driven by international trade. As a result, the average wage increases, which per se might cancel out the negative impact of trade on wages. Put differently, the measured average wages of working women doesn’t change, while the unmeasured potential wages of nonworking women decrease, so that the change in the measured average wage for working women doesn’t reveal the full impact of NAFTA. Indeed, Column (1) in Table 6 shows that $\beta'$ is not significantly different from zero.

To correct for the positive selection bias, we define the wage to be zero for all individuals that don’t have a wage income in our data. Doing so, we preserve the full sample throughout our analysis. While the imputed zero wages affects 37% – 55% of females, it affects 43% – 64% of males during the periods considered. We then estimate the model from (20), where the dependent variable is now defined via wages at the different percentiles of the wage distribution. Columns (2)-(5) in Table 6 show that, overall, the estimates are negative and, in the case of 90th and 85th percentiles, significant. Notice that the different percentiles chosen cover almost the whole distribution of the working sample.
4 Concluding Remarks

This paper analyzes how expansions and contractions of sectors that use female labor intensively affect aggregate female labor force participation. A first part of the paper develops a model to show that when international trade expands sectors conductive to female employment, female labor force participation drops and \textit{vice versa}. Intuitively, this effect arises since, when an economy specializes in sectors intensively use female labor, other sectors contract and male workers move to the expanding sectors, driving female workers out of formal employment.

In a second part of the paper, we test our theory using bilateral trade data for the U.S. and Mexico. We exploit U.S. cross-state variation in the exposure to trade with Mexico to examine how trade has impacted female labor force participation and female relative wage. Instrumenting trade shares with geographic distance, our cross-state regressions support the hypothesis that, in rich economies, international trade with poor countries tends to reduce female labor supply. These findings are robust to various definitions of female labor supply and a set of controls.
Table 1: Characteristics of U.S. data, 1990/91 and 2006/07

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<tr>
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<th>1990/91</th>
<th>2006/07</th>
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<tbody>
<tr>
<td><strong>FEMALE</strong></td>
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<td>Education (%)</td>
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<tr>
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<td></td>
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<td>(1.84)</td>
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<td></td>
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<td>(2.22)</td>
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<td>Employment (%)</td>
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<tr>
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<td>(5.2)</td>
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<tr>
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<td></td>
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<td>(1.81)</td>
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<td>Employment (%)</td>
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<td>(11307)</td>
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<td>Unemployment (%)</td>
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<td>4.82</td>
</tr>
<tr>
<td></td>
<td>(1.36)</td>
<td>(1.09)</td>
</tr>
<tr>
<td>Mexican Immigrants (%)</td>
<td>1.47</td>
<td>2.94</td>
</tr>
<tr>
<td></td>
<td>(3.03)</td>
<td>(3.69)</td>
</tr>
</tbody>
</table>

Note.- Gross state standard deviations are in parentheses. Data for education, labor participation, wages and Mexican immigrants are from IPUMS-CPS, data for trade are from World Institute for Strategic Economic Research and data for Gross State Product are from the Bureau of Economic Analysis. State Education rate is measured by the share of civilians aged 16–65 that have, at least, some college. Employment is the share of the working group out of the population aged 16–65. Per capita Gross State Product data are chained 2000 dollars. Trade share data are calculated as two fold export volumes over GSP. Census sample weights are used for all calculations.
Table 2: The Effect of U.S. Trade with Mexico on U.S. Female Labor Force Participation during the period 1990/91–2006/07

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
<th>(6)</th>
</tr>
</thead>
<tbody>
<tr>
<td>∆ Trade with Mexico</td>
<td>-0.280</td>
<td>-0.806*</td>
<td>-1.506***</td>
<td>-1.879***</td>
<td>-1.268***</td>
<td>-1.259***</td>
</tr>
<tr>
<td></td>
<td>(0.201)</td>
<td>(0.409)</td>
<td>(0.420)</td>
<td>(0.689)</td>
<td>(0.424)</td>
<td>(0.445)</td>
</tr>
<tr>
<td>FLFP in 1980/81</td>
<td>-0.248***</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.060)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FLFP in 1990/91</td>
<td></td>
<td>-0.635***</td>
<td>-0.760***</td>
<td>-0.629***</td>
<td>-0.601***</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.157)</td>
<td>(0.179)</td>
<td>(0.129)</td>
<td>(0.152)</td>
<td></td>
</tr>
<tr>
<td>∆ ln(GSP per capita)</td>
<td></td>
<td>0.020</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.016)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>∆ Unemployment</td>
<td></td>
<td></td>
<td>0.490**</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(0.213)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>∆ Females’ Education</td>
<td></td>
<td></td>
<td></td>
<td>0.125**</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(0.051)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>∆ Mexican immigrants</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>-14.010</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(12.342)</td>
<td></td>
</tr>
</tbody>
</table>

First-Stage Coefficients (Dependent Variable: ∆ Trade)

| Distance                  | -2.134***   | -2.021*** | -1.989*** | -2.004*** | -1.850*** |
|                          | (0.544)     | (0.581)   | (0.584)   | (0.597)   | (0.629)   |

First-Stage Coefficients (Dependent Variable: FLFP in 1990/91)

| FLFP in 1980/81           | 0.529***    | 0.563***  | 0.527***  | 0.531***  |
|                          | (0.066)     | (0.069)   | (0.063)   | (0.068)   |

Number of obs 51 51 51 51 51 51

Estimation Method (OLS) (IV) (IV) (IV) (IV) (IV)

Note.-Robust standard errors adjusted for heteroscedasticity are reported in parentheses. All models are weighted by CPS sampling weights. See the note to Table 1 for additional sample details and variables definition.
Table 3: The Effect of U.S. Trade with Mexico on U.S. Female Labor Force Participation

<table>
<thead>
<tr>
<th>Dependent Variable:</th>
<th>Change in Females Share in Average Hours Worked</th>
<th>Employment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>TX (1) Excluding TX, HI&amp;AK (2) TX, HI&amp;AK (3)</td>
<td></td>
</tr>
<tr>
<td>∆ Trade with Mexico</td>
<td>-1.917*** (0.500) -1.103*** (0.331) -1.363*** (0.519)</td>
<td></td>
</tr>
<tr>
<td>FLFP in 1990/91</td>
<td>-0.684*** (0.170) -0.629*** (0.162) -0.655*** (0.175)</td>
<td></td>
</tr>
<tr>
<td>Number of obs</td>
<td>50 49 48 51 51 51 51</td>
<td>51</td>
</tr>
</tbody>
</table>

First-Stage Coefficients (Dependent Variable: ∆ Trade)

<table>
<thead>
<tr>
<th>Distance</th>
<th>TX (1) Excluding TX, HI&amp;AK (2) TX, HI&amp;AK (3)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>∆ Trade with Mexico</td>
<td>-1.409** (0.540) -3.866*** (0.802) -2.837*** (0.815)</td>
<td></td>
</tr>
<tr>
<td>FLFP in 1980/81</td>
<td>0.532*** (0.067) 0.555*** (0.060) 0.552*** (0.060)</td>
<td></td>
</tr>
<tr>
<td>Number of obs</td>
<td>50 49 48 51 51 51 51</td>
<td>51</td>
</tr>
</tbody>
</table>

First-Stage Coefficients (Dependent Variable: FLFP in 1990/91)

<table>
<thead>
<tr>
<th>FLFP in 1990/91</th>
<th>TX (1) Excluding TX, HI&amp;AK (2) TX, HI&amp;AK (3)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>∆ Trade with Mexico</td>
<td>0.532*** (0.067) 0.555*** (0.060) 0.552*** (0.060)</td>
<td></td>
</tr>
<tr>
<td>Number of obs</td>
<td>50 49 48 51 51 51 51</td>
<td>51</td>
</tr>
</tbody>
</table>

Note: Robust standard errors adjusted for heteroscedasticity are reported in parentheses. All the above regressions are conducted according to the model described in Column 3 in Table 2. See the note to Table 1 for additional sample details and variables definition.
Table 4: The effect of U.S. trade with Mexico on U.S. Females/Males Labor Force Participation

<table>
<thead>
<tr>
<th>State Weight</th>
<th>FEMALE</th>
<th></th>
<th>MALE</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Hours worked</td>
<td>Employment</td>
<td>Hours worked</td>
<td>Employment</td>
</tr>
<tr>
<td></td>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
<td>(4)</td>
</tr>
<tr>
<td>∆ Trade with Mexico</td>
<td>0.60***</td>
<td>(0.38)</td>
<td>0.39***</td>
<td>(0.17)</td>
</tr>
<tr>
<td>LFP in 1990/91</td>
<td>0.93***</td>
<td>(0.11)</td>
<td>0.93***</td>
<td>(0.12)</td>
</tr>
<tr>
<td>Distance</td>
<td>−2.06***</td>
<td>(0.56)</td>
<td>−4.79***</td>
<td>(0.68)</td>
</tr>
<tr>
<td>LFP in 1980/81</td>
<td>0.67***</td>
<td>(0.07)</td>
<td>0.79***</td>
<td>(0.08)</td>
</tr>
<tr>
<td>Number of obs</td>
<td>51</td>
<td>51</td>
<td>51</td>
<td>51</td>
</tr>
</tbody>
</table>

Note.-Robust standard errors adjusted for heteroscedasticity are reported in parentheses. All regressions are conducted according to the model described in Column 3 in Table 2. The independent variables are instrumented by distance and the according Labor Force Participation shares in 1980/81. Regressions described in Columns 2, 4, 6 and 8 are weighted by state population size. See the note to Table 1 for additional sample details and variables definition.
Table 5: The effect of U.S. trade with Mexico on U.S. Females/Males Labor Force Participation (for skilled population)

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>FEMALE</th>
<th></th>
<th>MALE</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Hours worked</td>
<td>Employment</td>
<td>Hours worked</td>
<td>Employment</td>
</tr>
<tr>
<td></td>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
<td>(4)</td>
</tr>
<tr>
<td>Δ Trade with Mexico</td>
<td>-0.76***</td>
<td>-0.51***</td>
<td>-0.02**</td>
<td>-0.01**</td>
</tr>
<tr>
<td></td>
<td>(0.25)</td>
<td>(0.15)</td>
<td>(0.01)</td>
<td>(0.00)</td>
</tr>
<tr>
<td>LFP in 1990/91</td>
<td>-0.29***</td>
<td>-0.43***</td>
<td>-0.29***</td>
<td>-0.42***</td>
</tr>
<tr>
<td></td>
<td>(0.1)</td>
<td>(0.08)</td>
<td>(0.08)</td>
<td>(0.11)</td>
</tr>
</tbody>
</table>

First-Stage Coefficients (Dependent Variable: Δ Trade)

| Distance | -2.12*** | -4.9*** | -2.1*** | -4.76*** | -2.04*** | -4.36*** | -2.07*** | -4.54*** |
|          | (0.55) | (0.74) | (0.55) | (0.67) | (0.57) | (0.73) | (0.58) | (0.72) |

First-Stage Coefficients (Dependent Variable: LFP in 1990/91)

| LFP in 1980/81 | 0.75*** | 0.84*** | 0.76*** | 0.88*** | 0.61*** | 0.73*** | 0.61*** | 0.61*** |
|               | (0.12) | (0.13) | (0.12) | (0.12) | (0.07) | (0.09) | (0.07) | (0.08) |

| Number of obs | 51 | 51 | 51 | 51 | 51 | 51 | 51 | 51 |

Note.-Robust standard errors adjusted for heteroscedasticity are reported in parentheses. All regressions are conducted according to the model described in Column 3 in Table 2. The independent variables are instrumented by distance and the according Labor Force Participation shares in 1980/81. We define skilled individuals by those who are at least high school graduates. Regressions described in Columns 2, 4, 6 and 8 are weighted by state population size. See the note to Table 1 for additional sample details and variables definition.
Table 6: The effect of U.S. trade with Mexico on U.S. Females’ Relative Hourly Wage: \((w_f/w_m)\)

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>Female wage over male based on:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Average Wage</td>
<td>Wage from the following percentiles</td>
</tr>
<tr>
<td></td>
<td>(1)</td>
<td>(2)</td>
</tr>
<tr>
<td>(\Delta) Trade with Mexico</td>
<td>0.022 (0.036)</td>
<td>-0.049** (0.024)</td>
</tr>
<tr>
<td>(w_f/w_m) in 1990/91</td>
<td>-0.179 (0.563)</td>
<td>-0.687** (0.338)</td>
</tr>
</tbody>
</table>

First-Stage Coefficients (Dependent Variable: \(\Delta\) Trade)

| Distance | -3.011*** (0.803) | -2.958*** (0.825) | -2.878*** (0.836) | -2.885*** (0.825) | -2.91*** (0.807) |

First-Stage Coefficients (Dependent Variable: \(w_f/w_m\) in 1990/91)

| \(w_f/w_m\) in 1980/81 | 0.683*** (0.132) | 0.417*** (0.104) | 0.659*** (0.119) | 0.685*** (0.112) | 0.654*** (0.87) |

Number of obs | 51 | 51 | 51 | 51 | 51

Note: Robust standard errors adjusted for heteroscedasticity are reported in parentheses. All regressions correspond to the model described in Column 3 in Table 2 in the case of labor supply. The independent variables are instrumented by distance and the according relative females’ wage 1980/81. See the note to Table 1 for additional sample details and variables definition.
Appendix I
Proofs

Proof of Lemma 1. (i) Show that $Y_1/X_1$ and $Y_2/X_2$ cannot simultaneously increase in $\bar{Z}$ for $Z \neq Y$. Assume that they do. In the first case, where

$$
\frac{Y_1}{X_1} > \left(\frac{\bar{Y} - Y_1}{\bar{X} - X_1}\right) 
$$

holds one has (dots indicate derivatives w.r.t. $\bar{Z}$)

$$
\begin{align*}
\dot{Y}_1/Y_1 &> \frac{\dot{X}_1/X_1}{-(\delta_{XX} - \dot{X}_1)/X_1} \\
-\dot{Y}_1/(\bar{Y} - Y_1) &> (\delta_{XZ} - \dot{X}_1)/(\bar{X} - X_1)
\end{align*}
$$

($\delta_{XX} = 1, \delta_{XZ} = 0$ if $X \neq Z$). Together with (27) the second inequality in (28) implies

$$
\dot{Y}_1/Y_1 < \left(-\delta_{XZ} + \dot{X}_1\right)/X_1
$$

contradicting the first inequality in (28). In the second case, were (27) is violated, the above equation implies together with the second inequality of (28)

$$
-\dot{Y}_1/Y_1 > (\delta_{XZ} - \dot{X}_1)/X_1
$$

again contradicting the first inequality in (28).
(ii) Show that at most one of the four ratios $K_i/L_i$ and $M_i/L_i$ increases in $\bar{L}$ ($i = 1, 2$). By HD0 of $\nabla F^i$ the first order conditions to (5) can be written as

$$
p_1 \nabla F^1 \begin{pmatrix} K_1/L_1 \\ 1 \\ M_1/L_1 \end{pmatrix} = p_2 \nabla F^2 \begin{pmatrix} K_2/L_2 \\ 1 \\ M_2/L_2 \end{pmatrix}
$$

Assume that $K_1/L_1$ and $M_1/L_1$ increase in $\bar{L}$. By (i) this implies that $K_2/L_2$ and $M_2/L_2$ decrease in $\bar{L}$. Hence, by (2), $p_1 F^1_L$ increases and $p_2 F^2_L$ decreases. This contradicts the optimality condition $p_1 F^1_L = p_2 F^2_L$. Assume, instead, that $K_1/L_1$ and $M_2/L_2$ increase in $\bar{L}$, so that $K_2/L_2$ and $M_1/L_1$ decrease. Again by (2), $p_1 F^1_M$ increases and $p_2 F^2_M$ decreases, contradicting optimality. Switching indices covers the remaining cases.
(iii) Show $dF^i_L/d\bar{L} < 0$. By (ii), for each $i = 1, 2$, at least one of the ratios $K_i/L_i$ and $M_i/K_i$ decreases in $\bar{L}$. By (2) and

$$
F^i_L ((K_i, M_i, L_i)^i) = F^i_L ((K_i/L_i, M_i/L_i, 1)^i)
$$
this implies that $F^i_L$ decreases in $\bar{L}$.

(iv) Show $dF^i_M/d\bar{L} > 0$. Applying (i) to $K_i/M_i$ and $M_i/K_i$ shows that the ratio $K_i/M_i$ increases in $\bar{L}$ for exactly one $i$. Let wlog $M_1/K_1$ increase and $M_2/L_2$ decrease in $\bar{L}$. Now, write the first order conditions to (6) as

$$p_1 \nabla F^1 \begin{pmatrix} 1 \\ L_1/K_1 \\ M_1/K_1 \end{pmatrix} = p_2 \nabla F^2 \begin{pmatrix} 1 \\ L_2/K_2 \\ M_2/K_2 \end{pmatrix}$$

By (i), $L_i/K_i$ increases for at least one $i$. In case that $L_1/K_1$ increases and $L_2/K_2$ decreases, (2) implies that $F^1_K$ increases while $F^2_K$ decreases, contradicting optimality. If $L_1/K_1$ decreases and $L_2/K_2$ increases, then $F^1_M$ decreases while $F^2_M$ increases contradicting optimality. Hence, $L_i/K_i$ increase for $i = 1, 2$. Therefore, $F^2_M$ increases in $\bar{L}$.

(i) - (iv) prove (7) for $X = M$ and $Y = L$; the other cases follow by permutation of the factors.

Appendix II
A Falsification Test

In our falsification test we conduct the following triple difference exercise. We compare the explanatory power of distance to Mexico for the change in female labor force participation in two different periods: first, 1990–2000, in which we observe a substantial increase in U.S.-Mexican trade; and second, 1960–1970, when U.S.-Mexican trade was stagnant (Figure 2). We simply label these periods by “NAFTA episode” and “pre-NAFTA episode” respectively. We employ the Integrated Public Use Microdata Series (IPUMS-USA) of the decennial censuses data (Ruggles, Sobek, Alexander, Fitch, Goeken, Kelly Hall, King, and Ronnander (2009)). This source provides us with employment data for men and women for the years 1950, 1960 and 1970 for the pre-NAFTA episode, and 1980, 1990 and 2000 for the NAFTA episode. Table 7 below summarizes these reduced form regressions of the change in female labor force participation directly on distance in the two episodes and shows that during the NAFTA episode the coefficients of distance are positive and significant while in the pre-NAFTA episode are negative and not consistently significant. We read this as additional support to the validity of our instrument.
Table 7: Explanatory Power of Distance on Female Labor Force Participation

<table>
<thead>
<tr>
<th>Dependent Variable: Change in Share of Hours Worked</th>
<th>Relative Employment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>pre NAFTA</td>
</tr>
<tr>
<td>distance</td>
<td>(1)</td>
</tr>
<tr>
<td></td>
<td>-3.933***</td>
</tr>
<tr>
<td></td>
<td>(1.44)</td>
</tr>
<tr>
<td>Initial FLFP</td>
<td>-0.009</td>
</tr>
<tr>
<td></td>
<td>(0.111)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>First-Stage Coefficients (Dependent Variable: Initial level for FLFP)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lagged FLFP</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

Number of obs 42 51 42 51

Note.-Robust standard errors adjusted for heteroscedasticity are reported in parentheses. In all regressions FLFP is regressed on distance and the initial level of FLFP. The dependent variables, relative employment described in Columns 3 & 4 is the ratio of females employment over males employment. The initial level of FLFP is instrumented by its lagged level. The pre-NAFTA period is 1960–1970 and the NAFTA period is 1990–2000. Lagged levels are 1950 and 1980, respectively. For the pre-NAFTA period part of the data are missing for 9 states, which are Alaska, Delaware, Hawaii, Idaho, Montana, North Dakota, South Dakota, Vermont and Wyoming. Restricting our NAFTA period regressions to the same 42 states does not affect neither the magnitudes of coefficients nor their significance. See the note to Table 1 for additional sample details and variables definition.
References


