International Trade, the Gender Wage Gap, Female Labor Force Participation and Growth*

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Abstract

This paper analyzes the effect of international trade on the gender wage gap and the resulting impact on households' trade-off between female labor force participation (FLFP) and fertility. We argue that whenever trade expands sectors intensive in female labor, the gender wage gap widens and FLFP falls. In a model where male labor and female labor are two distinct factors of production we distinguish between a female intensive sector and a corresponding male intensive sector. Since the female intensive sector is also the capital intensive one, trade integration of a capital-abundant economy brings about a price increase of the good produced in the female intensive sector. This price increase generates the following two economic forces. First, it raises the factor rewards and, in particular, female wages. However, as male wages are affected proportionately the gender wage gap and therefore FLFP remain constant. Second, the price increase induces a factor reallocation, consisting mainly of male labor, from the male intensive sector to the female intensive one. This factor reallocation dilutes the capital intensity in the female-intensive sector. The relatively high complementarity between capital and female labor causes the marginal productivity of females to drop more than that of males, the gender wage gap widens and FLFP falls. We provide empirical evidence on U.S.-Mexican trade flows that supports our theory.

Keywords: Trade, Female Labor Force Participation, Gender Wage Gap, Fertility, Home Production, Growth, Convergence, NAFTA.

JEL Classifications: F10, F16, J13, J16.

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1 Introduction

The causes and consequences of female labor force participation and trade integration are two major research areas in economics. While research abounds on either of these research areas separately, the literature addressing the interplay between them remains strikingly scarce. This paper provides an empirical and a theoretical study of how international trade, by affecting demand for male and female labor, impacts the gender wage gap and thus female labor force participation. Surprisingly, our theory suggests that when trade expands sectors intensive in female labor, aggregate female labor shares drop.

Our theory builds on the model developed in Galor and Weil (1996). As in this earlier work, female labor and male labor are imperfect substitutes, which makes them two distinct factors of production.[1] These two factors are aggregated along with capital in a technology that exhibits a stronger complementarity between capital and female labor than between capital and male labor so that an increase in the capital stock closes the gender wage gap.[2] The preference structure implies that households split their time between childrearing and formal employment.[3] Households' optimization, however, requires that females raise children, while males are always fully employed. Finally, female labor supply increases as the gender wage gap closes, but is independent of the level of real wage since proportional increases in male and female wages have offsetting income and substitution effects.

To allow for international trade, we extend the model of Galor and Weil (1996), introducing two sectors with different factor intensities, which produce two tradable goods. We distinguish between a sector with relatively high demand for female labor labeled the *female*

[1] Acemoglu, Autor, and Lyle (2004) have utilized the large positive shock to demand for female labor induced by World War II to understand the effect of an increase in female labor supply on females' and males' wages. They find that a 10% increase in female labor input decreases females' wages by about 7% − 8%, but reduces males' wages by only 3% − 5%. The authors infer that the elasticity of substitution between female and male labor ranges between 2.5 and 3.5.

[2] Goldin (1990) argues that the rapid accumulation of capital during the nineteenth century, which characterized industrialization, was responsible for a dramatic increase in the relative wage of women.

[3] Goldin (1995) provides evidence that shows that few women in the 1940s and 1950s birth cohorts were able to combine childbearing with strong labor-force attachment. Angrist and Evans (1998) and Bailey (2006) find a negative causal effect running from fertility to female labor force participation.

intensive sector and the corresponding *male intensive sector*.[4] For simplicity, we assume that the male intensive sector requires only male labor as input. Therefore, the female intensive sector is also the capital intensive sector while the male intensive sector is the labor intensive one. Capital is constrained to remain within national borders. Just as in ordinary Heckscher-Ohlin-type models, the cross-country differences in capital-labor ratios in combination with differences in cross-sector intensities generate patterns of comparative advantage and motives for trade. Therefore, for a capital-abundant economy, trade brings about an increase in the price of the good produced in the female intensive sector. This prices increase, in turn, induces the capital-abundant economy to specialize in the female intensive sector and generates the following two economic forces. First, it raises the factor rewards and, in particular, female wages. However, as male wages are affected proportionately the gender wage gap and therefore female labor force participation remain constant. Second, the price increase expands the production in this sector and induces an inflow of factors to the expanding sector. Given the lower capital intensity in the male-intensive sector, the factors reallocation comprises more labor relative to capital, which dilutes the capital intensity in the female-intensive sector. Hence, the relatively high complementarity between capital and female labor causes the marginal productivity of females to drop more than that of males, the gender wage gap widens and female labor force participation falls.

Further, we show that the mechanism just described also applies in the case of technological progress that is biased towards the female intensive sector. Such technological progress increases the relative price of the good produced in the female intensive sector. By the mechanism above, mainly male labor reallocates to the female intensive sector - an effect strong enough to drive female workers out of formal employment. In this way, technological progress, biased towards the female intensive sector, might in turn curb female labor force participation.[5]

[4]Using data from United Nations Industrial Development Organization (UNIDO), which is highly disaggregated at the 3- and 4-digit level, we find that the variation across industries in the share of female workers is substantial: it ranges from zero to 100% with a mean of 25% and a standard deviation of 20%.

[5]For the role of technological progress in explaining the demographic transition, see Galor and Weil (2000)

Our paper has implications for economic growth. The dynamics of our autarkic economy are very similar to Galor and Weil (1996). As in this earlier work, increases in the capital labor ratio decreases the gender wage gap, leading females to substitute out of child rearing and into market labor. This choice, in turn, increases the savings rate and decreases population growth, which further increases the capital labor ratio. Since in the capital-scarce economy, international trade expands the male intensive sector and closes the gender wage gap, trade fosters female labor force participation and decreases fertility. However, the parallel impact of trade on capital accumulation in the capital-abundant economy is ambiguous. While international trade hinders female labor force participation and increases fertility, these adverse effects on capital accumulation may be dominated by the positive effects of the gains from trade on total savings. In either case, our model predicts that capital accumulation in the rich country falls short of capital accumulation in the poor country and, consequently, suggests convergence of per-household capital stocks.[6]

One may be concerned about the generality of our model and whether our results are driven by the specific modeling setup. For example, in the rich economy, our main mechanism depends on male migration from the male intensive sector to the female intensive one, which dilutes the capital labor ratio in the latter. What if the male intensive sector can use capital as a factor of production, which could also be reallocated? In the Third Appendix, we show that our findings still hold in a much more general setup. Specifically, we consider a two-sector economy with constant returns to scale technologies, where all factors are used in both sectors. We also assume that capital accumulation closes the gender wage gap.[7] These very mild assumptions are sufficient to generate the central "counter-intuitive result": whenever

and Galor and Moav (2002). For the impact of technological progress on fertility and female labor force participation, see Greenwood and Seshadri (2005) and Doepke, Hazan, and Maoz (2007).

[6]It is important to stress that our mechanism reveals the instant impact of trade on female labor force participation. One may still argues however that, in the long run, capital accumulation increases women's relative productivity and closes the gender wage gap and thus increases female labor force participation directly through the mechanism proposed by Galor and Weil (1996) or through other channels such as an increase female bargaining power, an increase in societal attitudes towards female labor and gender equality or through an increase in child care provision (Hazan and Zoabi 2012).

[7]This assumption is equivalent to our assumption, used in the current model, that the complementarity between capital and female labor is higher than the complementarity between capital and male labor.

the price of the good produced in the female intensive sector increases, the gender wage gap widens and, consequently, female labor force participation drops. The reason is that economy-wide complementarity between capital and female labor requires that the female intensive sector is also the capital intensive sector. Thus, there is relatively very little capital in the male intensive sector to begin with and hence little capital can be reallocated to the female intensive sector. Our general model also shows that, while aggregate female labor drops in response to trade liberalization, female employment in the female intensive sector may stay constant or actually increase. For an intuition of this finding, assume that output of the male intensive sector drop to zero in response to a trade shock. Obviously, female labor drops in the this dying sector. As long as this latter drop is larger than the drop in aggregate female employment (which is governed by the elasticity of household's female labor supply) female labor in the female intensive sector may indeed increase.

Since our assumption that the female labor intensive sector is also capital intensive is crucial, we feel the need to underpin it empirically. To this purpose, we use data from the UNIDO and analyze the relation between female and capital intensities.[8] Specifically, we regress female labor share on two different measures of the capital intensity at the 3- and 4-digit levels of disaggregation. Table 1 reports the results of a linear regression. All columns show that the coefficient is positive and significant, indicating a positive association between female and capital intensities. Moreover, the table shows that the more disaggregated data we use, the stronger is the significance. This is consistent with the view that our theory applies at the occupational level or even at the task level within each single industry.

Our theory generates the following testable predictions: when trading with a poor econ-

[8] We use the Industrial Statistics Database (INDSTAT4 - 2012 edition), which contains data on the manufacturing sector at the 3- and 4-digit level of disaggregation according to the International Standard Industrial Classification (ISIC) Revision 3. The data covers 151 manufacturing sectors and sub-sectors and 134 countries for the years 1990-2009 (unbalanced). The variables we are interested in are Number of employees, Number of female employees, Output, Value added and Gross fixed capital formation. Assuming a yearly depreciation rate of 5 percent, we use the capital formation to construct the capital stock for the period 2007-2008 at the industry level. The constructed capital stock allows us to build two different measures of capital intensity: capital stock over output and capital stock over value added. Finally, we define female intensity as the share of female employees over total number of employees.

Table 1: Female Labor Intensity and Capital Intensity across Industries

Capital Intensity Based on:	3-digit Output	3-digit Value Added	4-digit Output	4-digit Value Added
Dependent Variable: Average Female Labor Shares for the Years 2007/2008				
	(1)	(2)	(3)	(4)
Capital Intensity	0.075*	0.095**	0.092***	0.071***
	(0.044)	(0.042)	(0.024)	(0.022)
Intercept	−1.8***	−1.95***	−1.86***	−1.95***
	(0.041)	(0.079)	(0.023)	(0.041)
Observations	421	407	1554	1527
R2-Adjusted	0.573	0.572	0.435	0.430

NOTE.-Robust standard errors adjusted for heteroscedasticity are reported in parentheses. Female labor share is defined as the share of female employees out of total employees. Capital intensity is defined as either capital stock over output (Columns 1 and 3) or capital stock over value added (Columns 2 and 4). Columns 1 and 2 report the regression conducted on 3-digit data and Columns 3 and 4 report the regression conducted on 4-digit data.

omy, trade decreases female labor force participation and female relative wage in the rich economy. To test these predictions we use bilateral trade data for the U.S. (the capital rich economy) and Mexico (the capital scarce economy). Central to our estimation strategy are the differences between U.S. states in terms of their increase of trade with Mexico during the period 1990-2007.[9] We exploit an exogenous source of cross-state variation in exposure to trade to examine their differential effects on female labor force participation and female relative wage in the U.S.[10]

In light of the potential endogeneity of the change in trade shares, we instrument changes in trade shares by geographic distance and thus identify the impact of exogenous variation in changes in trade shares.[11] Consistent with our theory's predictions, the analysis reveals

[9]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.

[10]Our approach is similar to Campbell and Lapham (2004), who exploit variations in exposure to international trade to identify the effect of international trade shocks.

[11]Our model actually predicts that higher female labor force participation strengthens the comparative

statistically significant negative impacts of trade on female labor force participation and female relative wage.

To measure the effects of trade on female labor participation, 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. We find that changes in trade shares – instrumented by geographical distance – have negative and highly significant impacts on both measures of female labor force participation. Importantly, our results remain 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 for 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 and find that our results still hold.

Moving to the effects of trade on female relative wage, we define the dependent variable in our regressions as the ratio between females' average wage to males' average wage. Mulligan and Rubinstein (2008) find that the reduction in the gender wage gap during the period 1975-2001 can be attributed to a change in the sign of a selection bias from negative during the 1970s to positive during the 1990s. Accordingly, the presumption in our analysis is that the selection bias during the 1990s was positive. This selection bias mitigates the negative impact of trade on female relative wages as the less able women leave the labor market. Indeed, in our baseline regression, we find that the impact of trade on female *average* relative wage is insignificant. We correct for this negative selection bias by including individuals without reported wage at the lower end of the wage distribution and running the regressions on different percentiles of this new wage distribution. Consistent with our theory, our results reveal a negative impact of trade on female relative wage.

A brief explanation of our empirical strategy seems appropriate. One may argue that

advantage in the capital-intensive sector, which generates higher international specialization and trade.

focusing on aggregate female labor is not the most direct way to test our theory but rather examining the reallocations of male and female labor across sectors. However, two crucial reasons dictate our choice. First, our predictions regarding female labor participation concern aggregate female labor but do not apply at the industry-, firm- or plant-level. Specifically, female workers, laid off in the shrinking sector, may partly return to home production and partly migrate to the expanding sector, so that female labor in the expanding sector rises (see Third Appendix). Our theory thus predicts that female labor drops in the contracting sector and in aggregate. Testing its decrease in the contracting sector is hardly supportive to our theory and therefore, we test the aggregate decline. The second reason for our empirical strategy is the following: the empirical trade literature found that industry-level data hide substantial intra-industry product heterogeneity (Schott 2003). Moreover, Schott (2004) reports that capital-abundant economies use their endowment advantage to produce vertically different varieties. Finally, Bernard, Jensen, and Schott (2006) documents that, as industry exposure to imports from low-wage countries rises, labor in U.S. manufacturing reallocates away from labor-intensive plants and toward capital-intensive plants within industries. Overall, our theory may affect labor reallocation at the intra-industry level: either across vertically superior varieties or across plants with different capital intensities so that industry level data reveals only part of the trade-induced labor reallocation.

The present study connects to various literatures. On the theory side, our general framework is that of Heckscher-Ohlin-type models (Helpman and Krugman 1985). Given our focus on female labor shares, we need to model a non-trivial elasticity of female labor supply. Doing so, we depart from the conventional approach in which factor endowments are viewed as given and trade patterns are explored, but examine instead how trade affects the supply of factors and female labor force participation. Our paper also connects to the trade literature that analyzes the impact of trade on unemployment (Davis 1998, Helpman and Itskhoki 2010). Moving to understanding the gender wage gap, our paper is related to a different body of literature that explains the transition in the gender wage gap (Welch 2000, Gosling 2003, Black and Spitz-Oener 2010). Our modeling setup corresponds to this literature by taking primary attributes as the source of the gender wage gap.

Until recently, our understanding of the impact of international trade on the gender wage gap and female labor force participation was limited to Becker (1971), who argues that trade increases competition among firms and, thus, reduces costly discrimination and closes the gender wage gap. Tests of this hypothesis have generally produced mixed support (Black and Brainerd 2004, Berik, van der Meulen, and Zveglich 2004). Our mechanism, by contrast, operates in perfectly competitive markets through the differential impact of trade on different factors. However, this issue is getting some more focus. Interestingly, while in our empirical analysis we concentrate on one side of the NAFTA agreement and examine the impact of NAFTA on female labor force participation and female relative wage in the U.S., Aguayo-Tellez, Airola, and Juhn (2010) do so for Mexico. Consistent with our model, Aguayo-Tellez, Airola, and Juhn (2010) find that, during the 1990s, trade liberalization increased women's employment and women's bargaining power within the households.[12] One should bear in mind, however, that while their evidence goes hand in hand with the general trends of increasing female labor force participation and female relative wage, our evidence goes against these general trends. Autor, Dorn, and Hanson (2012) use the same period, $1990-2007$ in order to examine the impact of rising Chinese import competition on U.S. labor market outcomes. Consistent with our theory's prediction and empirical finding, Autor, Dorn, and Hanson (2012) find that both males' and females' employment and wages decreased and their unemployment increased and that these changes where stronger for females. Finally, our paper shares features of Galor and Mountford (2008) in the sense that both theories address the effect of international trade on households' optimal choices. Galor and Mountford (2008) endogenized educational choice and fertility choice, arguing that the gains from trade are channeled towards population growth in non-industrial countries while

[12]For understanding the progress in women's employment in Mexico, Juhn, Ujhelyi, and Villegas-Sanchez (2012) advance the hypothesis of technology spillover and argue that trade liberalization causes some firms to start exporting and adopting modern technologies that induces higher female employment.

in industrial countries, they are directed towards investment in education and growth in output per-capita. Our theory, which disregards educational choice, highlights the impact on female labor force participation.[13]

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

2 The Model

In our modeling strategy we follow Galor and Weil (1996) by adopting a standard OLG model, incorporating the endogenous choice of fertility.[14] At time t the economy is populated by L_t households, each containing one adult man (a husband) and one adult woman (a wife). Individuals live for three periods: childhood, adulthood and old age. In childhood, individuals consume a fixed quantity of their parents' time. In adulthood, individuals raise children, supply labor to the market, and save their wages. In old age, individuals merely consume their savings. The capital stock in each period is equal to the aggregate savings of the previous period.

A key assumption is that men and women differ in their labor endowments. While men and women have equal endowments of mental labor units, men have more physical labor units than women. These differences translate into a gender wage gap, which, in turn, governs the trade-off between female labor force participation and fertility.

[13]It is worth stressing that our mechanism holds not only for child-rearing, but also for any home-produced good whose production requires a time investment on the part of individuals.

[14]Kimura and Yasui (2010) extends the model of Galor and Weil (1996) to include non-market work in order to explain the long run dynamics in fertility, male labor participation and female labor participation.

2.1 Production

2.1.1 Technologies

Two intermediate goods, X_1 and X_2 are assembled into a final good Y by the CES-technology:

$$Y_t = \left(\theta X_{1,t}^{\rho} + (1-\theta) X_{2,t}^{\rho}\right)^{1/\rho} \qquad \rho, \theta \in (0,1). \tag{1}$$

Intermediate goods are produced using three factors: capital K, physical labor L^p, and mental labor L^m. We want to reflect the fact that sectors vary in their factor intensity, in particular, in their intensity of mental and physical labor. These differences in the factor intensity, in turn, generate differences in demand for male and female labor across sectors. Specifically, we impose the following structure on production of intermediate goods:

$$\begin{aligned} X_{1,t} &= aK_t^{\alpha}(L_t^m)^{1-\alpha} + bL_{1,t}^p \\ X_{2,t} &= bL_{2,t}^p. \end{aligned} \tag{2}$$

The variables $L_{i,t}^p$ stand for the physical labor employed in sector i at time t, while L_t^m is the amount of mental labor in the first sector at time t.[15]

2.1.2 Labor Endowments and Labor Allocation

Men and women are equally efficient in raising children. However, men and women differ in their endowments that are relevant for the labor market: while each woman is endowed with one unit of mental labor L^m, each man is endowed with one unit of mental labor L^m

[15] Examples of $X2$ production are agriculture, mining or construction if production is conducted in the traditional way. As for $X1$ production, on the one hand, the economic literature has identified an important role for incorporating the computer into the workplace in closing the gender wage gap. On the other hand, one may wonder of a sector that uses computers and still needs physical labor as an input of production. Our example of such a sector is a package delivery company such as UPS in the U.S. However, could this example be generalized to be presented at the macro level? Interestingly, Bacolod and Blum (2010) found that physical strength is required in 8 percent of the occupations of college graduates, 27 percent of high school graduates jobs and in 46 percent of jobs occupied by workers without a high school degree. This implies that, on average, individuals supply their physical strength in combination with mental skills even in highly skilled occupations.

plus one unit of physical labor L^p. Thus, as long as physical labor has a positive price, men receive a higher wage than women and therefore the opportunity cost of raising children is higher for a man than for a woman. Consequently, men only raise children when women are doing so full-time. Finally, we assume that a male worker cannot physically divide his two types labor and must allocate both units to only one sector. This means, in particular, that men employed in the X_2-sector waste their mental endowment.

2.2 Preferences

Individuals born at $(t-1)$ form households in period t and derive utility from the number of their children n_t and their joint old-age consumption c_{t+1} of a final good Y according to[16]

$$u_t = \gamma \ln(n_t) + (1-\gamma)\ln(c_{t+1}). \tag{3}$$

We assume that parents' time is the only input required to raise children and thus the opportunity cost of raising children is proportional to the market wage. Let w_t^F and w_t^M be the hourly wage of female and male workers, respectively. Normalizing the hours per period to unity, the full monetary income of a household is $w_t^M + w_t^F$ when wife and husband are both working full time.

Further, let z be the fraction of the time endowment of one parent that must be spent to raise one child. If the wife spends time raising children, then the marginal opportunity cost of a child is zw_t^F. If the husband spends time raising children, then the marginal opportunity cost of a child is zw_t^M. The household's budget constraint is therefore

$$\begin{aligned} w_t^F z n_t + s_t &\leq w_t^M + w_t^F \qquad if \qquad zn_t \leq 1 \\ w_t^F + w_t^M(zn_t - 1) + s_t &\leq w_t^M + w_t^F \qquad if \qquad zn_t > 1 \end{aligned} \tag{4}$$

[16]Note that since the basic unit is a household which consists a husband and wife, n_t is, in fact, the number of pairs of children that a couple has.

where s_t is the household's savings. In the third period, the household consumes its savings

$$c_{t+1} = s_t(1 + r_{t+1}) \tag{5}$$

where r_{t+1} is the net real interest rate on savings.

2.3 Optimality

It will prove useful to conduct the analysis in terms of per-household variables. We therefore define:

$$k_t = K_t/L_t \qquad\qquad m_t = L_t^m/L_t \qquad\qquad l_{i,t} = L_{i,t}^p/L_t$$

as capital, productive mental labor and sectorial physical labor *per-household*, respectively. Finally, we define

$$\kappa_t = k_t/m_t \tag{6}$$

as the ratio of capital to mental labor employed in the first sector. This ratio will play a central role in the following analysis.

2.3.1 Firms

Perfect competition in the final good sector implies, by (1) and (2), that the relative price is

$$\pi_t = \frac{p_{2,t}}{p_{1,t}} = \frac{1-\theta}{\theta}\left(\frac{X_{1,t}}{X_{2,t}}\right)^{1-\rho} = \frac{1-\theta}{\theta}\left(\frac{a\kappa_t^\alpha m_t + bl_{1,t}}{bl_{2,t}}\right)^{1-\rho}, \tag{7}$$

where we write $p_{i,t}$ as X_i's price in period t. Given $p_{i,t}$, cost minimizing final good producers leads us to the usual ideal price index P_t, which we normalize to one

$$P_t = \left(\left(\frac{\theta}{p_{1,t}^\rho}\right)^{1/(1-\rho)} + \left(\frac{1-\theta}{p_{2,t}^\rho}\right)^{1/(1-\rho)}\right)^{-(1-\rho)/\rho} = 1. \tag{8}$$

From equation (2) the return to capital in the first sector is

$$r_t = p_{1,t}\alpha a \kappa_t^{\alpha-1} \tag{9}$$

Wages are derived from (2) and reflect the marginal productivity of labor. Male shadow wages of the two sectors are determined by productivities and prices of the two sectors:

$$\begin{aligned} w_{1,t}^M &= p_{1,t}b[(1-\alpha)a/b\kappa_t^\alpha + 1] && (10) \\ w_{2,t}^M &= p_{2,t}b, && (11) \end{aligned}$$

These expressions reflect mental and physical labor productivity in the first sector, and physical labor productivity in the second sector. The prevailing market wage for male workers is then

$$w_t^M = \max\{w_{1,t}^M, w_{2,t}^M\} \tag{12}$$

Similarly, female shadow wage is

$$w_t^F = p_{1,t}(1-\alpha)a\kappa_t^\alpha, \tag{13}$$

which reflects mental labor productivity in the first sector.

2.3.2 Households

Household's maximizing problem yields

$$zn_t = \begin{cases} \gamma(1 + w_t^M/w_t^F) & if \quad \gamma(1 + w_t^M/w_t^F) \leq 1 \\ 2\gamma & if \quad 2\gamma \geq 1 \\ 1 & otherwise. \end{cases} \tag{14}$$

Equation (14) implies that in the case in which $\gamma \geq 1/2$ women raise children full time regardless of their wages. We rule out this scenario by imposing $\gamma < 1/2$. Under this restriction, women raise children full-time only under relatively high gender wage gaps. But as the gender gap decreases women join the labor force and fertility decreases. When w_t^F approaches w_t^M, women spend a fraction 2γ of their time raising children. Finally, under our assumption $\gamma < 1/2$ the budget constraint (4) collapses to

$$s_t = (1 - zn_t)w_t^F + w_t^M \tag{15}$$

and (14) becomes with $\omega_t = w_t^M / w_t^F$

$$zn_t = \min\left\{\gamma\left(1 + \omega_t\right), 1\right\}. \tag{16}$$

2.4 Closed Economy

2.4.1 Static Equilibrium

The equilibrium of the integrated economy is determined separately for two regimes. The first is a regime in which women do not participate in the formal labor market, and the second is a regime in which women participate. To simplify the analysis, we assume that, in equilibrium, the second sector is too small to accommodate all male labor. Specifically, we assume[17]

$$2 - \alpha \geq 1/\theta \tag{17}$$

to be satisfied throughout the following analysis. Under this assumption, $L_{1,t}^p > 0$ holds and the ratio of male to female wage can be computed by the marginal productivities in the first

[17] A sufficient condition for $l_{1,t} > 0$ is that the relative price (7) falls short of the ratio of marginal rates of transformation at $l_{1,t} = 0$ and $zn_t = 0$ i.e. $(1-\alpha)\kappa_t^\alpha a/b + 1 > (1-\theta)/\theta\,(\kappa_t^\alpha a/b)^{1-\rho}$. If $\kappa_t^\alpha a/b \geq 1$ then this sufficient condition is implied by $(1-\alpha) \geq (1-\theta)/\theta$, or (17). If $\kappa_t^\alpha a/b < 1$ instead, the sufficient condition is implied by $1 > (1-\theta)/\theta$ and hence, again, by (17).

sector

$$\omega_t = 1 + \frac{b}{(1-\alpha)a\kappa_t^\alpha}. \tag{18}$$

This ratio determines female labor force participation $1 - zn_t$ through (16)

$$zn_t = \min\left\{\gamma\left(2 + \frac{b}{(1-\alpha)a\kappa_t^\alpha}\right), 1\right\}. \tag{19}$$

To determine equilibrium κ_t, combine male wage (12), prices (7), and the resource constraint for male labor $1 = l_{1,t} + l_{2,t}$ to get

$$(1-\alpha)\frac{a}{b}\kappa_t^\alpha + 1 = \frac{1-\theta}{\theta}\left(\frac{\frac{a}{b}\kappa_t^\alpha m_t + l_{1,t}}{1 - l_{1,t}}\right)^{1-\rho}. \tag{20}$$

Further note that

$$l_{1,t} = m_t - (1 - zn_t) \tag{21}$$

so that equation (20) becomes

$$(1-\alpha)\frac{a}{b}\kappa_t^\alpha + 1 = \frac{1-\theta}{\theta}\left(\frac{\frac{a}{b}\kappa_t^\alpha m_t + m_t - (1 - zn_t)}{1 - m_t + (1 - zn_t)}\right)^{1-\rho}. \tag{22}$$

Equations (6), (19), and (22) determine m_t and zn_t and thus the equilibrium. There are two qualitatively different types of equilibria to distinguish.

The First Regime $zn_t = 1$. In the case in which $zn_t = 1$, equation (22) can be written in terms of κ_t (substitute $m_t = k_t/\kappa_t$):

$$(1-\alpha)\frac{a}{b}\kappa_t^\alpha + 1 = \frac{1-\theta}{\theta}\left(\frac{\frac{a}{b}\frac{k_t}{\kappa_t^{1-\alpha}} + \frac{k_t}{\kappa_t}}{1 - \frac{k_t}{\kappa_t}}\right)^{1-\rho}. \tag{23}$$

The Second Regime $zn_t < 1$. In case in which $zn_t < 1$ we use $m_t = k_t/\kappa_t$ and zn_t from (19) to write (22) as

$$(1-\alpha)\frac{a}{b}\kappa_t^{\alpha} + 1 = \frac{1-\theta}{\theta}\left(\frac{\frac{a}{b}\frac{k_t}{\kappa_t^{1-\alpha}} + \frac{k_t}{\kappa_t} - 1 + \gamma\left(2 + \frac{b}{a}\frac{\kappa_t^{-\alpha}}{1-\alpha}\right)}{1 - \frac{k_t}{\kappa_t} + 1 - \gamma\left(2 + \frac{b}{a}\frac{\kappa_t^{-\alpha}}{1-\alpha}\right)}\right)^{1-\rho}. \tag{24}$$

Equations (23) and (24) determine the equilibrium κ_t in the first and second regime, respectively. Notice that expressions on the left of both equations are increasing in κ_t, while both terms on the right are decreasing in κ_t. This implies that κ_t is unique in both regimes. Moreover, the expressions on the right of (23) and (24) are increasing in k_t so that $\kappa_t(k_t)$ is an increasing function.

Quite intuitively, a capital-rich economy has a higher capital-mental labor share than a capital-scarce economy. When going back to equation (19), this observation shows also that the higher the capital stock k_t of an economy, the lower fertility zn_t is. As $\kappa_t(k_t)|_{k_t=0} = 0$, (19) further implies that there is a $k_o > 0$ so that the economy is in the first regime when its capital stock falls short of k_o, while the economy is in the second regime if not. By combining the according condition $\gamma\left(2 + b/\left[(1-\alpha)a\kappa_o^{\alpha}\right]\right) = 1$ with equation (23) and $\kappa_o = k_o/m_o$, this threshold is shown to be

$$k_o = \theta\left(1-\gamma\right)\left(1 - 2\gamma + \gamma\frac{1-\alpha\theta}{1-\alpha}\right)^{-1}\left[\frac{(1-\alpha)(1-2\gamma)}{\gamma}\frac{a}{b}\right]^{-1/\alpha}. \tag{25}$$

At capital stocks below the threshold k_o all women raise children full-time. When capital is gradually accumulated and this threshold is passed, women integrate into the labor market and, as the variable κ_t keeps increasing, the gender wage gap closes and female labor supply rises. At the same time, and as a mirror image, fertility declines.

These observations regarding the impact of the capital stock on fertility and on female labor force participation bring us to the dynamics of the model.

2.4.2 Dynamics

The dynamics of the model are governed by two endogenous variables: savings s_t and fertility n_t. With the notation in per-household terms, the ratio of saving and fertility gives the next period's capital stock, i.e. $k_{t+1} = s_t/n_t$. Combining the budget constraint (15) and fertility (16) and distinguishing the two regimes, we can write

$$k_{t+1} = \frac{s_t}{n_t} = \begin{cases} zw_t^M & if \quad k_t < k_o \\ z\frac{1-\gamma}{\gamma}w_t^F & if \quad k_t \geq k_o. \end{cases} \tag{26}$$

Recalling that $\pi_t = \frac{p_{2,t}}{p_{1,t}}$, together with equations (10) and (11), leads to the following price ratio

$$\pi_t = (1-\alpha)\frac{a}{b}\kappa_t^\alpha + 1 \tag{27}$$

which, combined with the normalization (8), renders the price of the first intermediate good

$$p_{1,t} = \left(\theta^{1/(1-\rho)} + (1-\theta)^{1/(1-\rho)}\left(\frac{1}{(1-\alpha)\frac{a}{b}\kappa_t^\alpha + 1}\right)^{\rho/(1-\rho)}\right)^{(1-\rho)/\rho}.$$

With (10) - (13) and (26) we thus have

$$k_{t+1} = \begin{cases} zb\left(\theta^{\frac{1}{1-\rho}}\left((1-\alpha)\frac{a}{b}\kappa_t^\alpha + 1\right)^{\frac{\rho}{1-\rho}} + (1-\theta)^{\frac{1}{1-\rho}}\right)^{\frac{1-\rho}{\rho}} & if \quad k_t < k_o \\ zb\frac{1-\gamma}{\gamma}\left(\theta^{\frac{1}{1-\rho}}\left((1-\alpha)\frac{a}{b}\kappa_t^\alpha\right)^{\frac{\rho}{1-\rho}} + (1-\theta)^{\frac{1}{1-\rho}}\left(\frac{(1-\alpha)\frac{a}{b}\kappa_t^\alpha}{(1-\alpha)\frac{a}{b}\kappa_t^\alpha+1}\right)^{\frac{\rho}{1-\rho}}\right)^{\frac{1-\rho}{\rho}} & if \quad k_t \geq k_o. \end{cases} \tag{28}$$

These expressions show that in both regimes, k_{t+1} is increasing in κ_t and thus, since κ_t is an increasing function in k_t, the schedule $k_{t+1}(k_t)$ of the dynamic system is described by an increasing function.

We can now make two observations, which jointly imply the existence of a steady state under the second regime. First, the variable κ_t determined by (23) or (24) as well as the threshold capital stock (25), are independent of z. Thus, given that z is sufficiently large, an economy with per-household capital stock $k_t = k_o$ from (25) experiences positive capital growth due to capital accumulation (28): its capital stock in period $t+1$ exceeds its capital stock of the previous period, i.e. $k_{t+1} > k_t$ holds. Second, as k_t grows unbounded, the ratio $\kappa_t/k_t = 1/m_t$ is bounded from above.[18] Thus, dividing the second line on the right hand side of equation (28) by k_t shows that k_{t+1}/k_t approaches zero as k_t grows unbounded. Together, these findings imply that, if z is sufficiently large, the dynamic system has a steady state in the second regime.

Our knowledge about the dynamics and the steady state of the system is sufficient to tell a simple story about economic development and female labor force participation. In an economy where capital is scarce, female labor force participation is zero. As time passes and per-household capital stock gradually accumulates, the rewards of formal employment for female workers increase relative to rewards for male workers. This closing of the gender wage gap fosters female labor force participation and curbs fertility. Both effects accelerate per-household capital accumulation, which continues under the second regime up to the point where the economy reaches its steady state.

Up to this point, our two-sector model essentially replicates the main features of the model in Galor and Weil (1996). Rather than proving robustness of their results in a two-sector setting, our intention is to analyze the impact of international trade and specialization. We turn to this task next.

2.5 International Trade

We now turn to the effects of international trade in goods.[19] As trade induces specialization at the country level, countries expand some sectors while contracting others. As sectors differ in intensity of male and female labor, international specialization affects relative wages within each country. In the following paragraphs, we explore these effects of trade on the

[18] See Appendix.

[19] We assume that capital is immobile, i.e. it is restricted to remain within national borders. This is partly motivated by the strong home-bias of investment and, more importantly for our purpose, by the fact that differences in the factor content of trade are consistent with the Heckscher-Ohlin predictions (Debaere 2003).

gender wage gap and the consequences for fertility and female labor force participation.

We assume that the world consists of two countries, Home (no *) and Foreign (*). In addition, the superscript ^{A} indicates autarky variables, while its absence indicates variables of the free trade equilibrium. Moreover, we denote the relative population size of Foreign to Home by $\lambda_t = L_t^*/L_t$.

Writing $\bar{k}_t$ for the average per household capital stock of the world economy, we define the set of all possible factor distributions in a world as:

$$FD_t = \left\{ (\lambda_t, k_t, k_t^*) \mid \lambda_t \in [0, \infty];\ k_t, k_t^* \geq 0 \text{ and } (k_t + \lambda_t k_t^*) / (1 + \lambda_t) = \bar{k}_t \right\}, \tag{29}$$

This definition comprises all possible partitions of the capital stock. Notice that the definition depends on the world capital ratio $\bar{k}_t$ but is independent of the world population size $L_t+L_t^*$.[20]

2.5.1 Factor Price Equalization

A good starting point for the analysis of the free trade equilibrium is the Factor Price Equalization Set[21]

$$FPES_t = \left\{ (\lambda_t, k_t, k_t^*) \in FD_t \mid w^M = w^{*,M},\ w^F = w^{*,F},\ r = r^* \right\}. \tag{30}$$

Among all possible distributions of factors across countries, the $FPES_t$ comprises those that lead to free trade equilibria characterized by identical factor prices across countries. In terms of prices and output, these equilibria then replicate the equilibrium of an integrated world economy where factors are not restricted by national borders.[22] Thus, the $FPES_t$ describes the conditions on factor distributions under which borders do not affect the world efficiency

[20]The definition thus slightly deviates from the standard definition in the sense that it is formulated "modulo population size."

[21]Remember that the absence of superscript ^{A} indicates equilibrium variables under free trade – *e.g.* at w^M, $w^{*,M}$ etc.

[22]If the equilibrium of the integrated economy is replicated, factors in all countries must equalize. Conversely, if factor and good prices equalize in both countries, the world equilibrium is an equilibrium of the integrated economy.

frontier. Loosely conceptualized, a factor allocation is an element of the $FPES_t$ if relative factors are distributed "not too unevenly".

The following proposition conveniently characterizes the $FPES_t$ of the present model.

Proposition 1

Factor prices equalize if and only if $\kappa_t^* = \kappa_t$.

Proof. See Appendix. ■

The proposition shows that $\kappa_t = \kappa_t^* = \bar{\kappa}_t$ implies $\omega_t = \omega_t^*$, a regime in which fertility, determined by (16), equalizes in both countries: $zn_t = zn_t^* = z\bar{n}_t$.[23] Combining these equations leads to:

$$\bar{\kappa}_t = \frac{k_t}{l_{1,t} + 1 - z\bar{n}_t} = \frac{k_t^*}{l_{1,t}^* + 1 - z\bar{n}_t}. \tag{31}$$

By the definition of the $FPES_t$, $\bar{\kappa}_t$ and $\bar{n}_t$ are also the capital-mental labor ratio and fertility of the integrated world economy.

For the rest of the analysis, and without loss of generality Home will represent the capital scarce and Foreign the capital abundant country, i.e., we assume that $k_t < k_t^*$ for the initial period. Making use of this inequlality in combination with (31), we observe that $l_{1,t} < l_{1,t}^*$ and thus $l_{2,t} > l_{2,t}^*$. Consequently, the relevant resource constraints $l_{1,t}, l_{2,t}^* \leq 1$ lead to a restriction on capital stock conditions for factor price equalization to hold:

$$(1 - z\bar{n}_t)\bar{\kappa}_t \leq k_t, k_t^* \leq (2 - z\bar{n}_t)\bar{\kappa}_t \tag{32}$$

As capital stocks of both countries add up to the aggregate world capital stock ($\bar{k}_t = (k_t + \lambda_t k_t^*)/(1 + \lambda_t)$), the $FPES_t$ is described by (32) and

$$\lambda_t = \frac{\bar{k}_t - k_t}{k_t^* - \bar{k}_t}. \tag{33}$$

[23] Upper bars indicate variables of the integrated economy.

Using the concise graphical representation from Helpman and Krugman (1985), Figure 1 illustrates the $FPES_t$. Each point A on the plane represents a partition of world labor and world capital: the distance between the vertical axis and A represents Home's male labor L_t, while the distance between the horizontal axis and A represents Home's capital K_t; Foreign's variables are $L_t^* = \bar{L}_t - L_t$ and $K_t^* = \bar{K}_t - K_t$, respectively. Since female labor shares are determined by the gender wage gap and hence by factor prices only, factor price equalization implies that female labor shares equalize in both countries. Thus, in the case where global female labor shares are positive, Home must hold a minimum level of capital to keep X_1-production operating and generate jobs in this sector. This case is illustrated in the top panel of Figure 1. If, instead, global female labor shares are zero, Home may in fact entirely lack capital. By fully specializing on X_2-production, Home's factor prices may still equalize with Foreign's. In this case, which is illustrated by the bottom panel of Figure 1, the equilibrium of the integrated economy is replicated.

We can now readily determine the specialization pattern of both economies under the assumption that factor prices equalize. Recalling assumption $k_t < k_t^*$, we observe:

$$m_t = k_t/\bar{\kappa}_t < k_t^*/\bar{\kappa}_t = m_t^*,$$

while

$$l_{2,t} = 1 - [m_t - (1 - z\bar{n}_t)] > 1 - [m_t^* - (1 - z\bar{n}_t)] = l_{2,t}^*.$$

Confirming Heckscher-Ohlin-based intuition, the capital scarce Home country specializes in production of the labor intensive good, X_2, while capital abundant Foreign specializes in X_1-production.

We can further compare the trade equilibrium with the respective autarky equilibria. To do so, we use $\kappa_t^A < \bar{\kappa}_t < \kappa_t^{*,A}$ and (19) to conclude:

$$zn_t^A \geq z\bar{n}_t \geq zn_t^{*,A}.$$

These inequalities are strict if $1 > zn_t^A$ holds. Consequently, relative to autarky, trade increases female labor force participation in the capital scarce country and decreases it in the capital abundant country.

These observations combined imply that the country which, by international specialization, *contracts* the sector that is particularly suitable for female labor, experiences an *increase* in female labor force participation. Conversely, the country which *expands* the sector suitable for female labor, experiences a *decrease* in female labor force participation.

The reason for this seemingly paradoxical finding is the following. For each economy, the key determinant of female labor force participation is the gender wage gap $\omega_t^{(*)}$. In autarky and under factor price equalization, this gender wage gap is determined by the relative productivities in the X_1-sector via (18) and ultimately by the capital-mental labor ratio $\kappa_t^{(*)}$. When international specialization induces Home to contract its X_1-sector and expand its X_2-sector, male workers move from the first to the second sector, taking their mental labor with them. Thus, they increase the ratio κ_t and thereby foster female labor force participation $(1 - zn_t)$. Conversely, when Foreign workers react to trade-induced international price shifts and move from the second to the first sector, they dilute the capital-mental labor share κ_t^*, which increases the gender wage gap and decreases female labor force participation.[24]

In sum, under factor price equalization, we get sharp results on the impact of trade on female labor force participation in the capital scarce and abundant countries, respectively. The key mechanism for the result described above, however, depends on the fact that the gender wage gap is a function of the capital-mental labor ratio $\kappa_t^{(*)}$. The extent to which these results generalize beyond factor price equalization is the subject of the next subsection.

[24]The effect of relative productivities on the gender wage gap, which is the core of our mechanism operates under substantial generalizations. If $F(K, M, L)$ represents a standard constant return to scale production function in the first sector, it is sufficient to assume that capital K complements mental labor M relatively more than physical labor L (*i.e.* , $F_{KM}/F_M > F_{KL}/F_L \geq 0$, in line with Goldin (1990) and Galor and Weil (1996)) in order to generate the effect discussed. In particular, under these conditions, higher male employment in the first sector increases the gender wage gap (Sauré and Zoabi 2011).

2.5.2 Beyond Factor Price Equalization

Let us begin the general case of international trade by focusing on one country, for example, Home, with exogenous relative world prices π_t – i.e., for the moment, we assume that Home is a small open economy. We determine how the equilibrium gender wage gap ω_t changes with world price $\pi_t = p_{2,t}/p_{1,t}$. This is done in the following Lemma.

Lemma 1

(i) For given capital endowment k_t there are $\underline{\pi}, \overline{\pi}$ with $0 < \underline{\pi} < \pi_t^A < \overline{\pi}$ so that

$$\frac{d}{d\pi_t}\omega_t(\pi_t) = \begin{cases} 0 & \textit{if } \pi_t \leq \underline{\pi} \\ < 0 & \textit{if } \pi_t \in (\underline{\pi}, \overline{\pi}) \\ > 0 & \textit{if } \pi_t \geq \overline{\pi} \end{cases}$$

(ii) Output of the X_1- (X_2-) sector is weakly decreasing (increasing) in π_t.

Proof. (i) At autarky price π_t^A, we have $l_{1,t}, l_{2,t} > 0$, as shown in the closed economy. Combining (10), (11), and (13) we have $\pi_t = (1-\alpha)\, a/b\kappa_t^\alpha + 1$ and $\omega_t = \pi_t[(1-\alpha)\, a/b\kappa_t^\alpha]^{-1}$ and hence

$$\omega_t = \frac{\pi_t}{\pi_t - 1} \tag{34}$$

as long as $l_{1,t}, l_{2,t} > 0$, implying that ω_t is decreasing in π_t. By (16) this means that zn_t is decreasing in π_t, in this range too. Further, $\pi_t = (1-\alpha)\, a/b\kappa_t^\alpha + 1$ implies that $\kappa_t = k_t/m_t$ is increasing in π_t and hence, as $m_t = l_{1,t} + 1 - zn_t$, must be decreasing in π_t. Therefore, $l_{1,t}(\pi_t)$ is decreasing in π_t. The constraint $l_{1,t} \in [0,1]$ then implies that there are two prices $\underline{\pi}$ and $\overline{\pi}$ so that $l_{1,t}(\underline{\pi}) = 1$ and $l_{1,t}(\overline{\pi}) = 0$. Consider now prices π_t with $\pi_t \leq \underline{\pi}$ and check that (12) gives

$$\omega_t = 1 + [(1-\alpha)\, a/b\kappa_t^\alpha]^{-1} \tag{35}$$

Thus, ω_t is constant in π_t (check with (10) and (11) that $l_{1,t} = 1$ throughout this range). For prices π_t satisfying $\pi_t \geq \overline{\pi}$ (12) implies

$$\omega_t = \pi_t[(1-\alpha)\,a/b\kappa_t^{\alpha}]^{-1} \tag{36}$$

Thus, starting at $\pi_t = \overline{\pi}$, increases in π_t cannot increase $m_t = 1 - zn_t$ ((16) would require a decrease in ω_t contradicting equation (36)) and must widen the gender wage gap ω_t. Check with (10) and (11) that $l_{1,t} = 0$ throughout this range.

(ii) Output of X_2 is proportional to $1 - l_{1,t}$ and $l_{1,t}$ has been shown to be decreasing in (i). – Consider output of X_1. In the range $\pi_t < \underline{\pi}$, $l_{1,t} = 1$ and ω_t constant. Hence, $m_t = l_{1,t} + 1 - zn_t$ is constant and so is output of X_1. In the range $\pi_t \in (\underline{\pi}, \overline{\pi})$ the gender wage gap ω_t is decreasing and hence κ_t increases, as (18) holds. Thus, X_1 from (2) decreases. Finally, for $\pi_t > \overline{\pi}$ the employment $m_t = 1 - zn_t$ in X_1-sector decreases (ω_t increases while $l_{1,t} = 0$ holds). Thus, X_1 output falls. ■

Figure 2 summarizes part (i) of the Lemma. For small π_t, the gender wage gap $\omega_t(\pi_t)$ is constant: all factors are employed in the first sector and small price changes do not change the labor allocation, so that relative factor rewards are constant. Conversely, for $\pi_t > \bar{\pi}$, all male workers are employed in the second sector, while capital and female labor are employed in the first sector. Again, small price changes do not change the labor allocation, but translate one-to-one into changes in the wage gap. Finally, for the intermediate range $\pi_t \in (\underline{\pi}, \bar{\pi})$, the gender wage gap $\omega_t(\pi_t)$ is decreasing through the effects of labor allocation explained already in the case of factor price equalization. By the generic relation (16), these swings in ω_t are paralleled by swings in zn_t.

Part (ii) of the Lemma simply states the basic scheme of international trade: as import prices drop, an economy increases its import volume and shifts production towards its export sector.

Now consider the previously autarkic Home economy that suddenly opens up to trade and now faces relative world prices $\pi_t < \pi_t^A$. Relative to autarky, the gender wage gap ω_t increases (notice that $l_{1,t} > 0$ and compute $w_{M,t}/w_{F,t}$ with (10)-(13)). Hence, fertility n_t rises while female labor participation $(1 - zn_t)$ drops. At the same time trade expands the X_1-sector and contracts the X_2-sector. If, instead, $\pi_t > \pi_t^A$, then two outcomes are possible. First, if π_t is not too large, then the effect of trade is a reduction in the gender wage gap ω_t and thus a decrease in fertility n_t plus an increase in female labor force participation $(1 - zn_t)$. Second, if π_t is sufficiently large, then trade induces an increase in ω_t and n_t and a decrease in $(1 - zn_t)$. In Figure 2, the threshold that separates the two cases is labeled π_u.[25] In either case, trade contracts the X_1-sector and expands the X_2-sector.

Returning now to the trade equilibrium between capital scarce Home and capital abundant Foreign, we observe that the autarky prices of both countries are (18), so that, by the relative capital scarity, $\pi_t^A < \pi_t^{*,A}$ holds (compare (7)). In the regime with international trade, the world price π_t lies between the respective autarky prices:

$$\pi_t^A \leq \pi_t \leq \pi_t^{*,A}. \tag{37}$$

Thus, trade (weakly) increases relative prices π_t in Home while it (weakly) decreases them in Foreign. With this observation, we can apply the insights of Lemma 1. For the capital abundant Foreign, trade unambiguously causes a (weak) increase in the gender wage gap ω_t and thus a drop in female labor force participation. We can therefore generalize the first part of our result derived under factor price equalization. The country which, by international specialization, expands the sector suitable for female employment experiences a decrease in female labor force participation.

For capital scarce Home, however, trade induces a decrease in the wage gap ω_t and an increase in female labor force participation if and only if π_t is not too high (i.e., $\pi_t \leq \pi_u$

[25]Notice that this threshold π_u depends on the capital stock of the economy and could be written as $\pi_u(k_t)$.

holds).[26] In this restricted case, we recover the second part of the result derived under factor price equalization. The country which contracts the sector suitable for female labor experiences an increase in female labor force participation. This second observation is a non-trivial generalization of the parallel result under factor price equalization. To verify this statement, use that under free trade $l^*_{1,t} > 0$ and $l_{2,t} > 0$ hold so that, by (10) and (11)

$$(1-\alpha)\,\frac{a}{b}\,(\kappa^*_t)^\alpha + 1 \geq \pi_t \geq (1-\alpha)\,\frac{a}{b}\kappa^\alpha_t + 1 \tag{38}$$

holds. Proposition 1, however, states that factor price equalization requires $\kappa_t = \kappa^*_t$, implying $\pi_t = (1-\alpha)\,\frac{a}{b}\kappa^\alpha_t + 1$. By construction of $\overline{\pi}$, however, all world equilibria with $\pi_t \in (\overline{\pi}, \pi_u)$ are characterized by equality $\pi_t > (1-\alpha)\,\frac{a}{b}\kappa^\alpha_t + 1$, implying that factor prices do not equalize. Since finally, by construction of π_u we have $\omega_t > \omega^A_t$ for all equilibria with $\pi_t \in (\overline{\pi}, \pi_u)$ we conclude that trade induces an increase of female labor force participation in Home for a set of factor endowments that is strictly larger than the $FPES_t$.

Summarizing, we use the definitions (29) and (30) to state the following proposition.

Proposition 2

(i) In Foreign, trade expands the sector that uses female labor intensively, but unambiguously reduces female labor force participation.

(ii) There is a set $S_t \subset FD_t$ with $FPES_t \subsetneqq S_t$ and the following property: for each element of S_t trade contracts the sector that uses female labor intensively in Home, but increases Home's female labor force participation.

It is important to stress that this general result does not rely on the close link between female labor force participation and fertility. Instead any time-intensive home production will render the very same result.

Notice that, by virtue of the previous Lemma, the first statement of the proposition also holds at the margin. Any marginal trade liberalization in the capital rich country that lowers

[26] Notice that, by assumption (17) $\pi^{*,A}_t < \pi_u$ holds for Foreign. However, the threshold $\pi_u(k^*_t)$ depends on Foreign's capital and one cannot conclude that $\pi_t \leq \pi^{*,A}_t < \pi_u(k_t)$ holds.

the relative import over export price widens the gender wage gap and hence decreases female labor force participation.

2.5.3 Dynamics under Trade

We now turn to the dynamics of the model under free trade. Again, these are driven by two key variables, savings s_t and fertility n_t. Per-household capital stocks of either country follow the generic dynamic system equivalent to (26), now expanded to:

$$k_{t+1}^{(*)} = \begin{cases} zw_t^{M,(*)} & if \quad zn_t^{(*)} = 1 \\ z\frac{1-\gamma}{\gamma}w_t^{F,(*)} & if \quad zn_t^{(*)} < 1 \end{cases} \tag{39}$$

To calculate the respective wages, we can use the final good normalization (8) and the definition of π_t to derive:

$$p_{1,t} = \left(\theta^{\frac{1}{1-\rho}} + (1-\theta)^{\frac{1}{1-\rho}}\,\pi_t^{\frac{-\rho}{1-\rho}}\right)^{(1-\rho)/\rho} \quad \text{and} \quad p_{2,t} = \left(\theta^{\frac{1}{1-\rho}}\pi_t^{\frac{\rho}{1-\rho}} + (1-\theta)^{\frac{1}{1-\rho}}\right)^{(1-\rho)/\rho} \tag{40}$$

With these expressions, together with the definition of wages (10) - (13) and the dynamic system (39), we can shoe the following statements

Proposition 3

(i) $zn_t^* \leq zn_t$.

(ii) $k_{t+1}^* \geq k_{t+1}$.

(iii) If $\alpha(\theta/(1-\theta))^{\frac{1}{\rho-1}} \geq (1-2\gamma)/\gamma$ *holds then* $k_{t+1} \geq k_{t+1}^A$.

(iv) $k_{t+1}^*/k_{t+1} \leq k_{t+1}^{*,A}/k_{t+1}^A$.

Proof. See Appendix. ■

Parts (i) and (ii) of the proposition show that trade cannot reverse the order of countries regarding population growth or capital abundance. Relative to the poor country, the capital rich country has always weakly lower fertility rates, higher female labor force participation and a higher per-household capital stock.

Proposition 3 (iii) shows that, if the first sector is sufficiently large (i.e., $1-\theta$ is sufficiently small), trade unambiguously accelerates the pace of capital accumulation in the capital scarce country. It is worth emphasizing that this result also holds in the case where world prices π_t are very large and all men in Home work in the X_2-sector while female labor participation drops relative to autarky ($\pi_t > \pi_u$ in Figure 2). Even in this case, where a reduced female labor force participation depresses savings and increased population growth dilutes the following period's per household capital stock, the gains from trade are sufficient to grant a net increase in per-household capital accumulation relative to autarky. We cannot, however, make a parallel statement for the capital rich economy, for which the effect of trade on capital accumulation is ambiguous. Indeed, it can be shown that for capital accumulation in the rich economy, the positive forces stemming from the gains of trade might either dominate or be dominated by the adverse effect of reduced female labor force participation and higher fertility.

In sum, Proposition 3, shows that in transition to an economy's steady state, international trade fosters convergence in fertility, labor force participation, and per-household capital stocks. Notice, that we do not make any statements characterizing the steady states of the two economies. The reason for this restraint is that the steady state is not necessarily unique in our model. Therefore, there may be discrete long-run effects of trade on income and female labor force participation. A possible scenario is the following. A the poor economy trapped in a steady state with a low capital stock, low female labor force participation and high fertility (compare Galor and Weil (1996)). When this economy opens up to trade with a capital rich economy, the arising gains from trade and the reduced fertility rates lift this economy up, which consequentially escapes from the poverty trap by trading. In this case, international trade takes the role that Galor and Weil (1996) attriute to technological progress. Indeed, technological progress helps to eliminate poverty traps in the case of closed economies. We will briefly turn to this scenario next.

2.6 Technological Progress

The reduction in the gender wage gap is sometimes attributed to technological change. Welch (2000), Gosling (2003) and Black and Spitz-Oener (2010) argue that the increase in the market price for women's labor was brought about by a relative increase in the valuation of skill (mental labor endowments), which is, at least in part, explained by technological change. Galor and Weil (1996) show how technological change can eliminate poverty traps, characterized by high fertility, low female labor force participation and low per-household capital stocks. They argue that "technological progress will eventually eliminate such a development trap, leading to a period of rapid output growth and a rapid fertility transition" (p. 383).

Another popular hypothesis rests on demand shifts in favor of goods whose production is more intensive in skill or, more generally, in female labor inputs. The mechanism outlined above, in which male workers searching for the highest return to their labor crowd out women in the labor market sheds some doubt on the generality of these pro-growth effects. Indeed, we show next that the effect that leads to a decrease in female labor force participation and an increase in fertility in response to the expansion of the females' comparative advantage sector operates under technological change and shifts in demand as well.

For the formal analysis of technological change and demand shifts, we return to the closed economy. To incorporate technological change biased towards the sectors that generate demand for female labor, we rewrite the production functions (2) as:

$$
\begin{aligned}
X_1 &= \mu \left[a K_t^{\alpha} (L_t^m)^{1-\alpha} + b L_{1,t}^p \right] \\
X_2 &= b L_{2,t}^p
\end{aligned}
\tag{41}
$$

so that growth of the parameter $\mu \geq 1$ mimics technological progress that is biased towards the first sector. As a result of incorporating μ into our framework (24) becomes[27]

$$\frac{\theta}{1-\theta}\mu^{\rho}\left[(1-\alpha)\frac{a}{b}\kappa_t^{\alpha}+1\right]=\left(\frac{\frac{a}{b}\frac{k_t}{\kappa_t^{1-\alpha}}+\frac{k_t}{\kappa_t}-1+\gamma\left(2+\frac{b}{a}\frac{\kappa_t^{-\alpha}}{1-\alpha}\right)}{1-\frac{k_t}{\kappa_t}+1-\gamma\left(2+\frac{b}{a}\frac{\kappa_t^{-\alpha}}{1-\alpha}\right)}\right)^{1-\rho} \tag{42}$$

While the right hand side of (42) is decreasing in κ_t, the left hand side of (42) is increasing in κ_t and in μ, for $\rho \in (0,1)$. This implies that an increase in μ decreases the equilibrium level of κ_t, which, in turn, decreases female's productivity relative to male productivity, widens the gender wage gap and curbs female labor force participation.[28]

After reading the previous subsections, the intuition for this result is straightforward. An increase in μ increases male productivity in the first sector relative to the second sector. As long as the elasticity of substitution between X_1 and X_2 is greater than one, the relative price π decreases but the decrease is less than the increase in μ. As a result, male wage increases in the first sector, inducing male workers to move from the second sector to the first sector. This increases mental labor employed in the first sector and dilutes κ so that women's relative productivity declines, driving women out of formal employment into the child-rearing.

A similar mechanism applies under demand shifts towards the first good, equivalent to an increase in the parameter θ (compare (1)). Again, equation (42) shows that an increase in θ is followed by a decrease in κ_t, which curbs women's productivity by more than men's, widens the gender wage gap and thus decreases female labor force participation while fostering fertility.

In sum, our model shows that neither a technological change biased towards sectors with

[27]Under $\mu \geq 1$ condition (17) is sufficient for $l_{1,t}^p > 0$ to hold, i.e., male employment in the first sector is positive.

[28]The case is different for technological progress that is biased towards female labor directly. Such a case is captured by the case of increasing $\mu \geq 1$, where μ affects productivity of mental labor $\mu a K_t^{\alpha}(L_t^m)^{1-\alpha}+bL_{1,t}^p$, which acts just as an increase in the capital stock. This kind of technological progress, in turn, closes the gender wage gap and tends to integrate female workers to the labor force. We would label such a case as technological progress towards female labor, which is different from our current notion of technological progress biased towards sectors with high demand for female labor.

high demand for female labor nor demand shift towards goods of these sectors necessarily generates increases in female labor participation. The resulting increase in fertility generally counters the pro-growth effects.

3 Empirical Evidence

Our theory predicts that, when trading with a poor economy, trade decreases aggregate female labor force participation and female relative wage in the rich economy. We choose to test the predictions through the surge in U.S.-Mexican trade during the period 1990–2007, a period of trade liberalization, which we simply label the "NAFTA episode" in the following.[29]

A brief explanation of our empirical strategy seems appropriate. One may argue that focusing on aggregate female labor is not the most direct way to test our theory but rather examining the reallocations of male and female labor across sectors. However, two crucial reasons dictate our choice. First, the empirical trade literature found that industry-level data hide substantial intra-industry product heterogeneity (Schott 2003). Moreover, Schott (2004) reports that capital-abundant economies use their endowment advantage to produce vertically different varieties. Finally, Bernard, Jensen, and Schott (2006) documents that, as industry exposure to imports from low-wage countries rises, labor in U.S. manufacturing reallocates away from labor-intensive plants and toward capital-intensive plants within industries. Overall, our theory may affect labor reallocation at the intra-industry level: either across vertically superior varieties or across plants with different capital intensities so that industry level data reveals only part of the trade-induced labor reallocation. Second, and as we explain in the introduction, aggregate female labor drops in response to trade liberalization, while female employment in the female intensive sector may stay constant or actually increase.

[29] This 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) argues that Mexico's unilateral tariff reduction in the late 1980s and its abandoning of the exchange rate peg explains most 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.

The choice of the NAFTA episode has a number of virtues. First, the U.S. and Mexico are paradigmatic for a pair of capital-rich and capital-poor economies, for which our theory applies.[30] As a second advantage of the NAFTA episode, U.S.-Mexican trade experienced a substantial growth during that period: U.S. trade with Mexico as a share of U.S. GDP increased more than three-fold between 1990 and 2007, while Mexico's share in U.S. total trade rose by a factor of more than two (Figure 3). Via this substantial increase of bilateral trade volumes, we hope to identify a sizable impact of trade on labor markets. Third, 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.

In deciding whether to emphasize wages or employment in our empirical analysis, we notice that the empirical trade literature has documented an asymmetric impact of globalization on employment and wages. In particular, liberalization of goods markets appears to have a sizable effect on employment but a rather small effect on wages (Grossman 1987, Revenga 1992). This asymmetry may be a result of labor reallocation itself, which tends to erase wage differentials and mitigate wage effects. Alternatively, a selection bias problem blurs the impact of trade on wages as workers with specific characteristics systematically exit the labor market Therefore, our empirical part stresses the impact of exogenous change in trade on female labor force participation. However, to complete the picture, we also test for its impact on female relative wage.

[30] Capital stocks per worker can be calculated from real investment data as in PWT6.2. At depreciation rates of between .01 and .1, the relative capital stock of the U.S. in 2003 exceeded that 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).

3.1 Data

We rely on three different data sources. First, we use is the March Current Population Survey conducted by the Integrated Public Use Microdata Series (IPUMS-CPS).[31] 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 2 provides descriptive statistics for female and male labor for the years 1990/91 and 2006/07. Two observations can be drawn from Table 2 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,[32] which covers export data by state and destination country from 1988 onward. These data are disaggregated by goods categories (SIC from 1988 to 2000; NAICS from 1997 onward). Third, we use the Bureau of Economic Analysis for GDP data on the state level.[33]

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 to identify the effect of trade on the U.S. labor market (the capital rich economy). More precisely, 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.[34]

[31] King, Ruggles, Alexander, Flood, Genadek, Schroeder, Trampe, and Vick (2010).

[32] World Institute for Strategic Economic Research; data available under http://www.wisertrade.org. Cassey (2009) gives a good introduction to the data and their limitations.

[33] Data available under http: http://bea.doc.gov/regional/.

[34] 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

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 at all, and subsequently move our attention 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:

$$\Delta y_s = \alpha + \beta \Delta Trade_s + X_s' \gamma + u_s \tag{43}$$

where for any variable, z_s the s indicates the different U.S. states and Δ 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.[35] Our theory predicts that the estimate of β in (43) is negative.

We first run an OLS regression of the type described in (43). 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 edogeneity biases our OLS estimates and leaves us with the need to instrument so as to establish the desired causality.

differences in the gender 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 operates frictionless. Nevertheless, we expect to capture labor market effects to the extent that frictions of labor movement related to geographical distance impede a full equalization of factor prices across U.S. states.

[35] This time window is determined by availability of trade data. The data set includes entries for the years 1988/89 but these are of inferior quality.

We slightly modify the gravity equation of the trade literature and instrument $\Delta Trade_s$ by distance to Mexico.[36] Thus, our first stage regression is:

$$\Delta Trade_s = \mu + \theta \; d_s + X_s' \; \rho + \nu_s \tag{44}$$

where d_s is distance of state s to Mexico.

Figure 4 illustrates that distance is strongly correlated with the increase in trade share, thereby satisfying a first necessary condition for being a valid instrument.

Perhaps 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 include development, culture or religiosity, which typically correlate with latitude. However, by taking first difference we eliminate the state-fixed effect. It still may be the case that distance is correlated with pace at which female labor force participation changes. To verify this point, we perform the following additional 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 for our presumption that only during the NAFTA period does distance positively impact the change in female labor force participation, which suggests that the exclusion restriction is likely to hold.[37] One may still argue that during the NAFTA period changes in female labor force participation were more prominent than during the pre-NAFTA period. As a result, we observe the correlation between distance and changes in female labor force participation only during the NAFTA period. Our presumption here is that culture and religiosity have not changed during the period 1960–2000 and therefore if these characteristics were to impact the correlation between distance and the pace at which female labor force participation changes during the 90s, there is no reason to think that these same characteristics had no such impact

[36] More precisely, we regress trade volume as a percentage of Gross State Product on spherical distance of U.S. state capitals 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.

[37] Exact details about our falsification test are explained in the First Appendix and its results are reported in Table 8.

during the 60s. Moreover, looking at average female employment, it has increased during the pre-NAFTA period by about 20 percent (from 31.2 percent in 1960 to 37.4 percent in 1970) while it has increased during the NAFTA period by about 17 percent (from 54.4 percent in 1990 to 63.4 percent in 2000). This implies that the pace of change during the whole period was more or less the same.

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.[38] Further, we include the share of Mexican immigrants, which might either depress female labor participation – *e.g.* if cultural differences reduce gender labor market participation[39] – or else increase female labor participation – *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 the initial level of female labor force participation in the controls when estimating (43). A problem with this control variable, however, is that it is correlated with the error term in (43), wherefore we instrument it with lagged female labor participation (values from 1980/81). In choosing our instrument for the initial levels of female labor force partici-

[38]We define two categories of education. First, educated individuals who have at least some college-training 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.

[39]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.

pation we thus assume that the levels in 1980/81 affect the changes in female labor force participation during the period 1990/91–2006/7 only through the levels of 1990/91.

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. We further define exposure to trade as twice the state exports to Mexico over GSP. We restrict the study to export because import data per state are not available.[40] Distance is defined as spherical distance from state capitals to Mexico City.

Table 3 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, ΔTrade with Mexico, since this OLS regression suffers from a bias due to endogeneity problems. E.g. higher female labor force participation strengthens the comparative advantage in the capital-intensive sector, which generates higher international specialization and trade.

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.

[40] We assume that import equalizes export in order to reveal, quantitatively, a more realistic coefficient of trade on female labor share.

The coefficient of interest is the one on change in trade with Mexico (β). 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.

3.2.4 Robustness

We next conduct some robustness checks for the results obtained in the baseline regression (Column 3 in Table 3). 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 4), and hence in predicted trade shares. Table 4 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 4 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 4).[41] Results show that neither the point estimates nor the significance level are affected.

Since our theory rests on intra household optimization, it seems appropriate to restrict our sample to married individuals only. Column 6 in Table 4 shows that the point estimates

[41] Ground distance is measured in time and derived from maps.google.com.

remain 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 4 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 were 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 (1.89) and 32.2 (1.81), respectively (Table 2). These regressions are summarized in Table 5.[42] 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 labor hours: estimates are mostly insignificant, positive and around zero.

Finally, we limit our sample to highly educated individuals for several reasons. First, our theory suggests that female labor force participation drops due to the decrease in the relative price of mental labor, which may be associated with higher education. Second, this limitation eliminates the possibility that our estimated effects stem from alternative mechanisms.[43] Consistent with our theory, Table 6 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.

[42] Columns 2, 4, 6 and 8 in Table 5 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.

[43] Thus, one may conjecture that the estimates pick up a negative correlation between the share of unskilled women and distance from Mexico. In this case, in states neighboring Mexico, a larger share of women would be affected by adverse wage shocks due to trade, resulting in a larger drop in female labor force participation.

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 consensus exists in the literature that the impact of trade on wages is very weak we seek to investigate 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 (43), we analyze the relative wage on the state level with the following empirical model

$$\Delta\left(\frac{w^f}{w^m}\right)_s = \alpha' + \beta'\Delta Trade_s + X_s'\gamma' + v_s \tag{45}$$

The dependent variable $\Delta(\frac{w^f}{w^m})_s$ is the change in the relative wage of females in state s. We keep the same notation of section 3.2. Our theory predicts that the estimate of β' in (45) is negative.

We focus on one specification, which corresponds to the one in Column 3 of Table 3. Accordingly, our first stage regression is the same as in (44). We control for the initial level of relative wage, and in order to avoid its correlation with the error term in (45), we instrument it with a lagged female relative wage (values from 1980/81).

3.3.2 Regression Results

Table 7 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 don'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 7 shows that β' is not significantly different from zero.

To correct for the positive selection bias, we define the wage to be zero for all individuals who don't have a wage income in our data. Doing so, we preserve the full sample throughout our analysis. The shares of imputed zero wages vary over time and across states. These shares are $37\% - 55\%$ for females and $43\% - 64\%$ for males. We then estimating the model from (45), where the dependent variable is now defined via wages at the different percentiles of the wage distribution. Columns (2)-(5) in Table 7 show that, overall, the estimates are negative and, in the case of 90^{th} and 85^{th} percentiles, significant. Two observations are in order. First, the different percentiles chosen cover almost the whole distribution of the working sample. Second, the negative impact of trade on wages is stronger for higher percentiles of the wage distribution. This latter observation is consistent with the view that the females who are endowed with relatively high mental labor endowments are those whose wages are negatively affected by trade.

4 Concluding Remarks

This paper analyzes how expansions and contractions of sectors that use female labor intensively affect aggregate female labor force participation. We argue that when international trade expands sectors conductive to female employment, female labor force participation drops, and *vice versa*. This is because male workers earn higher wages than women and are therefore always formally employed. Thus, 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.

Turning to the dynamics, our model suggests that international trade fosters per-household capital growth in the capital-scarce economy. In the capital-abundant economy, however, the impact of international trade on capital growth is ambiguous. Although international trade hinders female labor force participation and increases fertility, domination of these adverse effects by positive forces stemming from gains from trade may occur. In both cases, our model suggests that trade cannot accelerate capital accumulation in the rich country by more than it accelerates capital accumulation in the poor country and, thus, our theory predicts convergence of per-household capital stocks.

Finally, 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.

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Figures & Tables

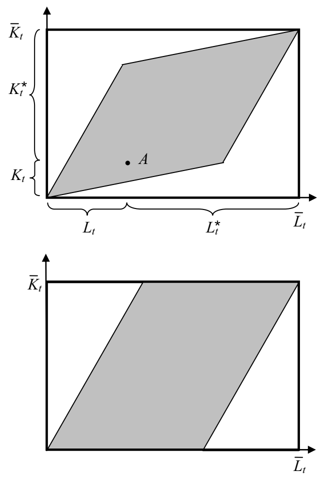


Figure 1: Factor Price Equalization Set

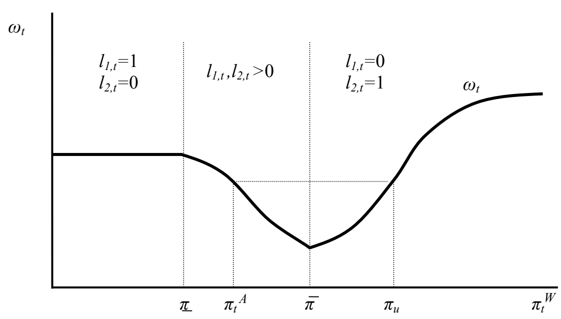


Figure 2: Gender Wage Gap and World Price

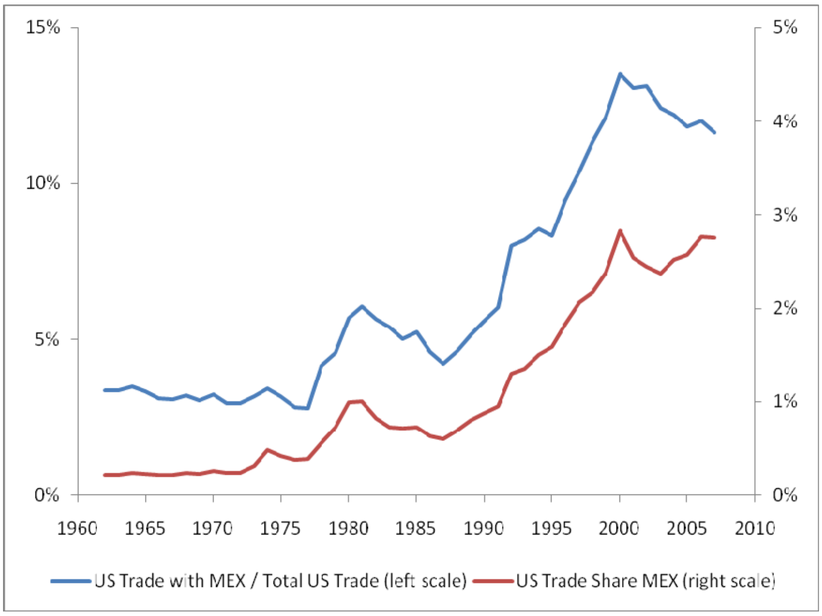
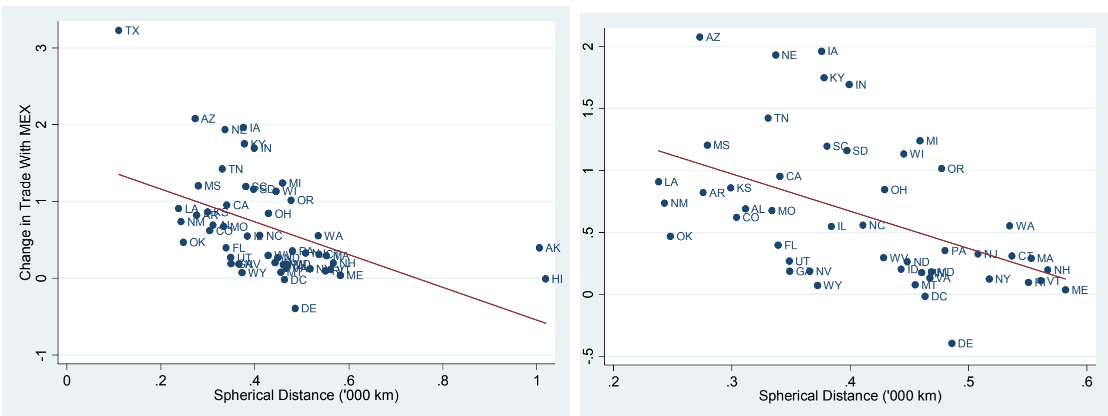


Figure 3: U.S. Trade Share – Imports plus Exports over GDP – with Mexico (red line, right scale) and Mexico's Share of U.S. Trade Volumes (blue line, left scale). Source: (1) Nominal GDP: are from Heston, Summers, and Aten (2006) and (2) US imports from and export to Mexico are from Feenstra, Lipsey, Deng, Ma, and Mo (2005) for the period 1962 - 2000 and from United States International Trade Commission for the period 2001 - 2008



slope = -2.13 t-statistic= -3.92

slope = -3 t-statistic= -3.75

Figure 4: Change in Trade with Mexico by State (1990-2007). left Panel: all states; right panel: excluding Alaska, Hawaii and Texas.

Table 2: Characteristics of U.S. Data, 1990/91 and 2006/07

	1990/91	2006/07
FEMALE		
Education (%)	39.38 (5.59)	56.55 (5.36)
Weekly hours worked	22.77 (1.92)	24.24 (1.84)
Hourly wage	11.39 (1.65)	14.55 (2.22)
Employment (%)	65 (5.2)	67 (4.7)
MALE		
Education (%)	41.21 (6.36)	50.87 (5.92)
Weekly hours worked	32.92 (1.89)	32.2 (1.81)
Hourly wage	15.84 (2.02)	19.14 (3.24)
Employment (%)	78 (3.6)	77 (4.2)
State		
per-capita GSP	28321 (11307)	37968 (13881)
Trade share (%)	0.53 (0.98)	1.21 (1.51)
Unemployment (%)	6.34 (1.36)	4.82 (1.09)
Mexican Immigrants (%)	1.47 (3.03)	2.94 (3.69)

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 3: The Effect of U.S. Trade with Mexico on U.S. Female Labor Force Participation during the period 1990/91–2006/07

	Dependent Variable: Change in Females Share in Average Hours Worked					
	(1)	(2)	(3)	(4)	(5)	(6)
Δ Trade	-0.280 (0.201)	-0.806^{*} (0.409)	-1.506^{***} (0.420)	-1.879^{***} (0.689)	-1.268^{***} (0.424)	-1.259^{***} (0.445)
FLFP 80/81	-0.248^{***} (0.060)					
FLFP 90/91			-0.635^{***} (0.157)	-0.760^{***} (0.179)	-0.629^{***} (0.129)	-0.601^{***} (0.152)
Δ ln(GSP)				0.020 (0.016)		
Δ Unemp				0.490^{**} (0.213)		
Δ Fem Edu					0.125^{**} (0.051)	
Δ Mex imm						−14.010 (12.342)
		First-Stage Coefficients (Dependent Variable: Δ Trade)				
Distance		-2.134^{***} (0.544)	-2.021^{***} (0.581)	-1.989^{***} (0.584)	-2.004^{***} (0.597)	-1.850^{***} (0.629)
FLFP 80/81			−0.023 (0.040)	−0.062 (0.038)	−0.023 (0.040)	−0.027 (0.040)
Joint F-test		15.39	12.66	12.63	12.08	10.53
		First-Stage Coefficients (Dependent Variable: FLFP in 1990/91)				
Distance			−0.223 (0.972)	−0.611 (1.061)	−0.666 (0.933)	−0.298 (1.059)
FLFP 80/81			0.529^{***} (0.066)	0.563^{***} (0.069)	0.527^{***} (0.063)	0.531^{***} (0.068)
Joint F-test			35.01	35.56	37.47	34.32
Obs	51	51	51	51	51	51
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. In the bottom part of the table we show the first stage coefficients for the corresponding specifications. We report only the coefficients of the two instruments and the F-test for the joint significance of the instruments. See the note to Table 2 for additional sample details and variables definition.

Table 4: The Effect of U.S. Trade with Mexico on U.S. Female Labor Force Participation

Dependent Variable:	Change in Females Share in						
	Average Hours Worked						Employment
	Excluding						
	TX	Hi&AK	TX, HI&AK	Trade in Manufacture	Distance in minutes	Married Couples	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Δ Trade with Mexico	-1.917^{***} (0.500)	-1.103^{***} (0.331)	-1.363^{**} (0.519)	-1.631^{***} (0.502)	-1.559^{***} (0.442)	-1.130^{**} (0.427)	-1.462^{**} (0.609)
FLFP in 1990/91	-0.684^{***} (0.170)	-0.629^{***} (0.162)	-0.655^{***} (0.175)	-0.599^{***} (0.150)	-0.671^{***} (0.167)	-0.539^{**} (0.250)	-0.663^{**} (0.251)
	First-Stage Coefficients (Dependent Variable: Δ Trade)						
Distance	-1.409^{**} (0.540)	-3.866^{***} (0.802)	-2.837^{***} (0.815)	-1.871^{***} (0.546)	-1.864^{***} (0.538)	-2.112^{***} (0.568)	-1.895^{***} (0.613)
	First-Stage Coefficients (Dependent Variable: FLFP in 1990/91)						
FLFP in 1980/81	0.532^{***} (0.067)	0.555^{***} (0.060)	0.552^{***} (0.060)	0.529^{***} (0.066)	0.545^{***} (0.062)	0.544^{***} (0.075)	0.556^{***} (0.097)
Number of obs	50	49	48	51	51	51	51

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 3. For each one of the first stage regressions we report only the relevant instrument. See the note to Table 2 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

	FEMALE				MALE			
Dependent Variable	Hours worked		Employment		Hours worked		Employment	
State Weight		+		+		+		+
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Δ Trade with Mexico	−0.72**	−0.65***	−0.02**	−0.02***	0.60	0.39**	0.01	0.01
	(0.27)	(0.17)	(0.01)	(0.01)	(0.38)	(0.17)	(0.01)	(0.00)
LFP in 1990/91	−0.25***	−0.42***	−0.29***	−0.39***	−0.08	−0.24**	0.11	0.01
	(0.08)	(0.07)	(0.08)	(0.08)	(0.13)	(0.09)	(0.11)	(0.09)
	First-Stage Coefficients (Dependent Variable: Δ Trade)							
Distance	−2.06***	−4.79***	−2.06***	−4.74***	−2.12***	−4.56***	−2.10***	−4.60***
	(0.56)	(0.68)	(0.57)	(0.67)	(0.56)	(0.71)	(0.56)	(0.71)
	First-Stage Coefficients (Dependent Variable: LFP in 1990/91)							
LFP in 1980/81	0.93***	0.93***	0.92***	0.90***	0.67***	0.79***	0.74***	0.82***
	(0.11)	(0.12)	(0.09)	(0.10)	(0.07)	(0.08)	(0.07)	(0.07)
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 3. The independent variables are instrumented by distance and the according Labor Force Participation shares in 1980/81. For each one of the first stage regressions we report only the relevant instrument. Regressions described in Columns 2, 4, 6 and 8 are weighted by state population size. See the note to Table 2 for additional sample details and variables definition.

Table 6: The Effect of U.S. Trade with Mexico on U.S. Females/Males Labor Force Participation (for skilled population)

Dependent Variable	FEMALE				MALE			
	Hours worked		Employment		Hours worked		Employment	
State Weight		+		+		+		+
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Δ Trade with Mexico	-0.76^{***}	-0.51^{***}	-0.02^{**}	-0.01^{**}	0.22	0.26^{*}	-0.01	-0.00
	(0.25)	(0.15)	(0.01)	(0.00)	(0.38)	(0.15)	(0.01)	(0.00)
LFP in 1990/91	-0.29^{***}	-0.43^{***}	-0.29^{***}	-0.42^{***}	-0.03	-0.19^{*}	0.51^{**}	0.36^{**}
	(0.1)	(0.08)	(0.08)	(0.11)	(0.09)	(0.1)	(0.21)	(0.19)
	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)	(0.13)	(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 3. The independent variables are instrumented by distance and the according Labor Force Participation shares in 1980/81. For each one of the first stage regressions we report only the relevant instrument. 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 2 for additional sample details and variables definition.

Table 7: The Effect of U.S. Trade with Mexico on U.S. Females' Relative Hourly Wage: (w^f/w^m)

Dependent Variable	Female wage over male based on:				
	Average Wage	Wage from the following percentiles			
		90^{th}	85^{th}	80^{th}	70^{th}
	(1)	(2)	(3)	(4)	(5)
Δ Trade with Mexico	0.022 (0.036)	-0.049^{**} (0.024)	-0.039^{*} (0.021)	-0.009 (0.019)	-0.011 (0.018)
w^f/w^m in 1990/91	-0.179 (0.563)	-0.687^{**} (0.338)	-0.674^{***} (0.207)	-0.469^{**} (0.209)	-0.16 (0.165)
	First-Stage Coefficients (Dependent Variable: Δ 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 3 in the case of labor supply. The independent variables are instrumented by distance and the according relative females wage 1980/81. For each one of the first stage regressions we report only the relevant instrument. See the note to Table 2 for additional sample details and variables definition.

First Appendix

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 3). 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 8 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 8: Explanatory Power of Distance on Female Labor Force Participation

Dependent Variable: Change in	Share of Hours Worked		Relative Employment	
	pre NAFTA	NAFTA	pre NAFTA	NAFTA
	(1)	(2)	(3)	(4)
distance	-3.933^{***}	2.703^{***}	-4.423	10.236^{***}
	(1.44)	(0.562)	(4.572)	(1.844)
Initial FLFP	-0.009	-0.544^{***}	-0.217	-0.736^{***}
	(0.111)	(0.08)	(0.134)	(0.125)
	First-Stage Coefficients (Dependent Variable: Initial level for FLFP)			
Lagged FLFP	0.675^{***}	0.593^{***}	0.753^{***}	0.632^{***}
	(0.085)	(0.039)	(0.047)	(0.068)
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 2 for additional sample details and variables definition.

Second Appendix

Proofs

Proof that $1/m_t$ is bounded above. First observe that $k_t \to \infty$ means $k_t > k_o$ so that the second regime applies. Use (24) to confirm that $\kappa_t \to \infty$ as $k_t \to \infty$ (else the denominator in the brackets of the expression on the right turns negative). Finally, divide equation (22) by κ_t^α to get

$$\frac{1-\theta}{\theta}\frac{1}{\kappa_t^{\alpha\rho}}\left(\frac{\frac{a}{b}m_t + [m_t - (1-zn_t)]\,\kappa_t^{-\alpha}}{1-m_t+(1-zn_t)}\right)^{1-\rho} \to (1-\alpha)\frac{a}{b} \qquad (k_t \to \infty).$$

Since this limit is positive, the term in brackets must approach infinity as $k_t \to \infty$ so that, as $\lim_{\kappa_t \to \infty} zn_t = 2\gamma$, $\lim_{k_t \to \infty} m_t = 2(1-\gamma)$ must hold. This proves that $1/m_t$ is bounded above. ■

Proof of Proposition 1. The proof of "$\Rightarrow$" is immediate by $r_t = r_t^*$ and (9).

For "$\Leftarrow$" assume that $\kappa_t^* = \kappa_t$, which implies $r_t = p_{1,t}\alpha a\kappa_t^{\alpha-1} = p_{1,t}\alpha a\left(\kappa_t^*\right)^{\alpha-1} = r_t^*$ and $w_t^F = p_{1,t}(1-\alpha)a\kappa_t^\alpha = p_{1,t}(1-\alpha)a\left(\kappa_t^*\right)^\alpha = w_t^{F,*}$. By $X_{2,t} > 0$ we have $l_{2,t} + l_{2,t}^* > 0$. In case $l_{2,t}^*, l_{2,t} > 0$ $w_t^M = w_t^{M,*}$ follows from (10). In case $l_{2,t}^* = 0$ this implies

$$w_t^M = p_{2,t}b \le w_t^{M,*}.$$

At the same time $l_{1,t}^* = 1$ implies

$$w_t^{M,*} = p_{1,t}((1-\alpha)a(\kappa_t^*)^\alpha + b) = p_{1,t}((1-\alpha)a\kappa_t^\alpha + b) \le w_t^M$$

so that $w_t^M = w_t^{M,*}$. In case $l_{2,t} = 0$ switching Home and Foreign variables leads to $w_t^M = w_t^{M,*}$ again. ■

Proof of Proposition 3. (i) By (16) it is sufficient to show $\omega_t^* \leq \omega_t$. Since free trade implies $l_{1,t}^* > 0$ and $l_{2,t} > 0$ we have $\omega_t = \pi_t b / \left[a\left(1-\alpha\right)\kappa_t^\alpha\right] \geq 1 + b/\left[a\left(1-\alpha\right)\kappa_t^\alpha\right]$ and $\omega_t^* = 1 + b/\left[a\left(1-\alpha\right)\left(\kappa_t^*\right)^\alpha\right] \geq \pi_t b/\left[a\left(1-\alpha\right)\left(\kappa_t^*\right)^\alpha\right]$. Combining these relations gives

$$\frac{\omega_t^*}{\omega_t} \leq \frac{\pi_t + \omega_t^*}{\pi_t + \omega_t}$$

and proves statement (i).

(ii) By (i) we have $zn_t^* \leq zn_t$ and distinguish two cases according to (16). The first, where $zn_t = 1$ holds, gives with (39)

$$\frac{k_{t+1}^*}{k_{t+1}} \geq \frac{w^{M,*}}{w^M} \geq \frac{p_{2,t}b}{p_{2,t}b} = 1$$

(We used $k_{t+1}^* \geq zw^{M,*}$ for the first inequality and $l_{2,t} > 0$ for the second.)

If, instead, $zn_t < 1$ holds, then (i) implies $zn_t^* < 1$ so that (39)

$$\frac{k_{t+1}^*}{k_{t+1}} = \frac{w^{F,*}}{w^F} = \frac{\omega_t}{\omega_t^*}\frac{w^{M,*}}{w^M} \geq \frac{w^{M,*}}{w^M} \geq 1$$

where we used (i) and (16) in the first inequality; the second inequality follows as above.

(iii) If $zn_t^A = 1$ we have

$$\frac{k_{t+1}^A}{k_{t+1}} \leq \frac{w^{M,A}}{w^M} = \frac{p_{2,t}^A b}{p_{2,t}b} \leq 1$$

If, instead, $zn_t^A < 1$ then $zn_t < 1$ (from (34) as long as $l_{1,t} > 0$ and $m_t > 0$ otherwise) and

$$\frac{k_{t+1}^A}{k_{t+1}} \leq \frac{w^{F,A}}{w^F} = \frac{\omega_t}{\omega_t^A}\frac{w^{M,A}}{w^M}$$

For the case $\omega_t \leq \omega_t^A$ (or $\pi_t \leq \pi_u$ in Figure 2) this proves the claim. If instead $\omega_t > \omega_t^A$ we use $\kappa_t = k_t/(1 - zn_t)$ and (16) to write

$$\kappa_t\left(1 - \gamma\left(1 + \pi_t \frac{b/a}{1-\alpha}\kappa_t^{-\alpha}\right)\right) = k_t$$

and take implicit derivatives

$$\frac{d\kappa_t}{d\pi_t} = \kappa_t \frac{1}{1-\alpha} \frac{\gamma}{(1-\gamma)a/b\kappa_t^{\alpha} - \gamma\pi_t}$$

At the same time (40) leads to

$$\frac{dp_{1,t}}{d\pi_t} = -p_{1,t}^{1-\frac{\rho}{1-\rho}} \left(\frac{1-\theta}{\pi_t}\right)^{\frac{1}{1-\rho}}$$

Thus,

$$\frac{d}{d\pi_t} \ln\left(p_{1,t}\kappa_t^{\alpha}\right) = \frac{\alpha}{1-\alpha} \frac{\gamma}{(1-\gamma)a/b\kappa_t^{\alpha} - \gamma\pi_t} - \left(\left(\frac{\theta}{1-\theta}\right)^{\frac{1}{1-\rho}} \pi_t^{\frac{\rho}{1-\rho}} + \pi_t^{\frac{-\rho}{1-\rho}}\right)^{-1} \pi_t^{-1}$$

A sufficient condition for this expression to be positive is

$$\frac{\alpha}{1-\alpha} \frac{\gamma}{\pi_t^{-1}(1-\gamma)a/b\kappa_t^{\alpha} - \gamma} > \frac{1}{\left(\frac{\theta}{1-\theta}\right)^{\frac{1}{1-\rho}} \pi_t^{\frac{\rho}{1-\rho}} + 1}$$

or with $\omega_t = \pi_t b / \left[a\left(1-\alpha\right)\kappa_t^{\alpha}\right]$

$$\frac{\alpha}{1-\alpha} \frac{\gamma}{\frac{1-\gamma}{1-\alpha}\frac{1}{\omega_t} - \gamma} > \frac{1}{\left(\frac{\theta}{1-\theta}\right)^{\frac{1}{1-\rho}} \pi_t^{\frac{\rho}{1-\rho}} + 1}$$

Since $\omega_t > 1$ and $\pi_t > 1$ this condition is satisfied whenever

$$\alpha \frac{\gamma}{1-\gamma-(1-\alpha)\gamma} > \frac{1}{\left(\frac{\theta}{1-\theta}\right)^{\frac{1}{1-\rho}} + 1}$$

or $(\theta/(1-\theta))^{\frac{1}{1-\rho}} \geq (1-2\gamma)/(\alpha\gamma)$ holds, proving the statement (iii).

(iv) Notice with Proposition 2 (i) that the first case, $zn_t^* < 1$, implies $k_{t+1}^*/k_{t+1}^{*,A} = p_{1,t}(\kappa_t^*)^{\alpha}/(p_{1,t}^{*,A}(\kappa_t^{*,A})^{\alpha})$. If $zn_t^* = 1$, instead, $k_{t+1}^*/k_{t+1}^{*,A} = p_{1,t}\left((1-\alpha)a\kappa_t^* + b\right)/(p_{1,t}^{*,A}((1-\alpha)a\kappa_t^{*,A}+b))$. Now, inequality (37) and expression (40) for the price $p_{1,t}^{(*,A)}$ imply $p_{1,t}/p_{1,t}^{*,A} \leq 1$.

Further, by $m_t^{*,A} \leq m_t^*$ we have $\kappa_t^{*,A} \geq \kappa_t^*$ and thus

$$k_{t+1}^*/k_{t+1}^{*,A} \leq \left(\kappa_t^*/\kappa_t^{*,A}\right)^\alpha$$

Similarly, we compute for $zn_t < 1$ that $k_{t+1}/k_{t+1}^A = p_{1,t}\kappa_t^\alpha/(p_{1,t}^A(\kappa_t^A)^\alpha)$ while for $zn_t = 1$ $k_{t+1}/k_{t+1}^A = p_{1,t}\left((1-\alpha)a\kappa_t^\alpha + b\right)/(p_{1,t}^A((1-\alpha)a(\kappa_t^A)^\alpha + b))$ holds. By (37) and expression (40) we have $p_{1,t}/p_{1,t}^A \geq 1$. Further, by $m_t^A \geq m_t$ we have $\kappa_t^A \geq \kappa_t$ and thus

$$k_{t+1}/k_{t+1}^A \geq \left(\kappa_t/\kappa_t^A\right)^\alpha$$

Combining both inequalities leads to

$$\frac{k_{t+1}^*/k_{t+1}^{*,A}}{k_{t+1}/k_{t+1}^A} \leq \left(\frac{\kappa_t^*/\kappa_t^{*,A}}{\kappa_t/\kappa_t^A}\right)^\alpha = \left(\frac{m_t^{*,A}/m_t^*}{m_t^A/m_t}\right)^\alpha$$

Using again $m_t^{*,A} \leq m_t^*$ and $m_t^A \geq m_t$ shows that the expression on the right falls weakly short of unity, which proves the statement. ■

Third Appendix

A Generalization of the Static Result

A The General Framework

The framework of our model economy is extremely 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.

A.1 The Setup

Regarding the framework of our model we try to be quite 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.

A.1.1 Production

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

$$Q_i = G^i(K, F, M) \qquad i = 1, 2. \tag{A-1}$$

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

$$G^i_X > 0;\ G^i_{XY} \geq 0 \quad \text{for } X \neq Y; \qquad G^i_{XX} < 0 \tag{A-2}$$

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

Sectors differ in their demand for F-type labor relative to M-type labor. Without loss of generality the first sector is relatively more intensive in F, i.e.[44]

$$F_1/\bar{F} > M_1/\bar{M} \tag{A-3}$$

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

A.1.2 Factors

The variable K stands for physical capital. For the variables F and M different interpretations are possible. First, F and M may stand for female and male labor, respectively. Under positive output in both sectors the Inada conditions imply positive employment of all factors in all industries. Hence, the male and female wage, denoted as w_M and w_F, respectively, are equal to the marginal product of corresponding labor, i.e.

$$w_M = p_1 G^1_M = p_2 G^2_M \qquad \text{and} \qquad w_F = p_1 G^1_F = p_2 G^2_F \tag{A-4}$$

holds. Alternatively, the factor F may stand for "brain" or mental inputs, while M stands for "brawn" or physical labor as in the main body of the paper. 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 F and one unit of M, while female workers

[44] With $\bar{F} = F_1 + F_2$ and $\bar{M} = M_1 + M_2$ it is immediate to check that this condition is equivalent to the condition $F_1/F_2 > M_1/M_2$ and thus to the condition $F_1/M_1 > F_2/M_2$, which may be more common.

owe one unit of F but $\beta < 1$ units of M. In this case, the contribution of mental labor rewards are relatively higher for female than for male workers. Whenever interior solutions prevail (*i.e.*, workers of both genders are employed in both sectors) wage equalization requires $p_1 \left(G_M^1 + G_F^1 \right) = p_2 \left(G_M^2 + G_F^2 \right)$ and $p_1 \left(\beta G_M^1 + G_F^1 \right) = p_2 \left(\beta G_M^2 + G_F^2 \right)$, which constitutes a system equivalent to (A-4). We will focus on interior solutions, so that both interpretations of F and M are, in terms of factor allocation, formally equivalent.

A.1.3 Preferences

Individuals consume the two goods Q_1 and Q_2. Concerning labor supply, we assume that (i) male labor is entirely inelastic and (ii) female labor supply depends only on the ratio of female to male wages, ω.

By the second assumption, we can write supply of female over male working hours as

$$R^s(\omega). \tag{A-5}$$

The superscript ^{s} indicates supply and ω stands for the ratio of F-factor price over M-factor price. The function R is assumed to be increasing in ω.

A.2 Inelastic Factor Supply

We begin our analysis by considering an economy with inelastic factor supply. Denoting the vector of factor endowments with $\bar{Z} = (\bar{K}, \bar{F}; \bar{M})^t$, we write $Z = (K_1, F_1, M_1)^t$ for the vector of factors employed in the Q_1-sector.

A.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)):

$$\max_{Z}\ p_1G^1(Z)+p_2G^2\left(\bar{Z}-Z\right) \tag{A-6}$$

We assume that the solution to (A-6) is unique and interior and we denoted it by $Z^*(\bar{Z})$.

Further, we denote w_X for the reward of factor X (w_M and w_F are defined in (A-4), the interest rate w_K is defined correspondingly) and formulate the following lemma.

Lemma A.1 *Assume prices p_i are constant, then (A-2) implies*

$$\frac{d}{d\bar{X}}\ln\left(\frac{w_X}{w_Y}\right)<0 \qquad X,Y=K,M,F \qquad Y\neq X \tag{A-7}$$

Proof. (i) Let $X,Y,\xi\in\{K,F,M\}$ and $\xi\neq Y$. Show that Y_1/X_1 and Y_2/X_2 cannot simultaneously increase in $\bar{\xi}$. Assume that they do, i.e.

$$\begin{aligned} \dot{Y}_1/Y_1 &> \dot{X}_1/X_1 \\ -\dot{Y}_1/(\bar{Y}-Y_1) &> (\delta_{X\xi}-\dot{X}_1)/(\bar{X}-X_1) \end{aligned} \tag{A-8}$$

holds, where dots indicate derivatives w.r.t. $\bar{\xi}$ and the Kronecker delta is defined as usual as $\delta_{\xi\xi}=1$, $\delta_{X\xi}=0$ if $X\neq Z$.

Consider now the two cases $Y_1/X_1>\left(\bar{Y}-Y_1\right)/\left(\bar{X}-X_1\right)$ and $Y_1/X_1<\left(\bar{Y}-Y_1\right)/\left(\bar{X}-X_1\right)$. In the first case

$$Y_1/X_1>\left(\bar{Y}-Y_1\right)/\left(\bar{X}-X_1\right), \tag{A-9}$$

the second inequality in (A-8) then implies

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

contradicting the first inequality in (A-8).

Consider the second case, were (A-9) is violated, so that the second inequality of (A-8)

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

contradicting the first inequality in (A-8).

(ii) Let $Y, X \in \{K, F, M\}$ and $Y \neq X$ and show that at most one of the four ratios Y_i/X_i $(i = 1, 2)$ increases in $\bar{X}$. Take $X = M$ and show that at most one of $K_1/M_1, K_2/M_2, F_1/M_1$ and F_2/M_2 increases in $\bar{M}$. All other cases follow identically.

By homogeneity of degree zero of the vector of derivatives $\nabla G^i = (dG^i/dK, dG^i/dF, dG^i/dM)^t$, the first order conditions to (A-6) can be written as

$$p_1 \nabla G^1 \begin{pmatrix} K_1/M_1 \\ 1 \\ F_1/M_1 \end{pmatrix} = p_2 \nabla G^2 \begin{pmatrix} K_2/M_2 \\ 1 \\ F_2/M_2 \end{pmatrix}$$

Assume that K_1/M_1 and F_1/M_1 increase in $\bar{M}$. By (i) this implies that K_2/M_2 and F_2/M_2 decrease in $\bar{M}$. Hence, by (A-2), $p_1 G^1_M$ increases and $p_2 G^2_M$ decreases. This contradicts the optimality condition $p_1 G^1_M = p_2 G^2_M$. Assume, instead, that K_1/M_1 and F_2/M_2 increase in $\bar{M}$, so that K_2/M_2 and F_1/M_1 decrease. Again by (A-2), $p_1 G^1_F$ increases and $p_2 G^2_F$ decreases, contradicting optimality. Switching indices covers the remaining cases.

(iii) Let $X \in \{K, F, M\}$ and show $dG^i_X/d\bar{X} < 0$. Take $X = M$ and show $dG^i_M/d\bar{M} < 0$; all other cases follow identically. By (ii), for each $i = 1, 2$, at least one of the ratios K_i/M_i and F_i/K_i decreases in $\bar{M}$. By (A-2) and

$$G^i_M\left((K_i, F_i, M_i)^t\right) = G^i_M\left((K_i/M_i, F_i/M_i, 1)^t\right)$$

this implies that G^i_M decreases in $\bar{M}$.

(iv) Let $X, Y \in \{K, F, M\}$ and $Y \neq X$ and show $dG^i_Y/d\bar{X} > 0$. Take $X = M$ and and $Y = F$; all other cases follow identically. Show $dG^i_F/d\bar{M} > 0$. Applying (i) to K_i/F_i and F_i/K_i shows that the ratio K_i/F_i increases in $\bar{M}$ for exactly one i. Let wlog F_1/K_1 increase and F_2/M_2 decrease in $\bar{M}$. Now, write the first order conditions to (A-6) as

$$p_1 \nabla G^1 \begin{pmatrix} 1 \\ M_1/K_1 \\ F_1/K_1 \end{pmatrix} = p_2 \nabla G^2 \begin{pmatrix} 1 \\ M_2/K_2 \\ F_2/K_2 \end{pmatrix}$$

By (i), M_i/K_i increases for at least one i. In case that M_1/K_1 increases and M_2/K_2 decreases, (A-2) implies that G_K^1 increases while G_K^2 decreases, contradicting optimality. If M_1/K_1 decreases and M_2/K_2 increases, then G_F^1 decreases while G_K^2 increases contradicting optimality. Hence, M_i/K_i increase for $i = 1, 2$. Therefore, G_F^2 increases in $\bar{M}$. ∎

The lemma states that an increase in aggregate supply of one factor decreases its price relative to the price of all other factors. Thus, the decreasing returns to each factor on the industry level translate, quite intuitively, to decreasing returns to the same factor on the aggregate, economy-wide level.

A.2.2 Effects of Capital Accumulation: the "Complementarity-Condition"

Having derived some intuitive results in our setup of a small open economy, we now impose our key assumption on the modeling framework. Specifically, we assume that an increase in the capital stock raises the rewards of F more than that of M:

$$\frac{d}{d\bar{K}} \ln \left(\frac{w_F}{w_M} \right) > 0. \tag{A-10}$$

Following Goldin (1990), an important branch of the economics of demography have argued that the accelerating capital accumulation has helped to closed the gender wage gap. Referring to her seminal contribution, we will refer to this inequality as the "Complementarity-Condition".[45]

It will prove useful to formulate the relations between equilibrium factor allocation and

[45] Below, we reformulate the "Complementarity-Condition" in terms of factor price elasticities.

factor prices in terms of demand elasticities. Doing so, however, we need to account for the fact that under technologies with constant return to scale, 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 relative to male labor: $k = K/M$ and $f = F/M$. The relation between factor allocation and factor prices is then

$$\begin{pmatrix} \Delta\hat{w}_K \\ \Delta\hat{w}_F \end{pmatrix} \equiv \begin{pmatrix} \hat{w}_K - \hat{w}_M \\ \hat{w}_F - \hat{w}_M \end{pmatrix} = \begin{pmatrix} \alpha_k^K & \alpha_f^K \\ \alpha_k^F & \alpha_f^F \end{pmatrix} \begin{pmatrix} \hat{k} \\ \hat{f} \end{pmatrix} \tag{A-11}$$

where we have set $\hat{X} = dX/X$ and $\alpha_y^X = \left[d\left(w_X/w_M\right)/dy\right] / \left[\left(w_X/w_M\right)/y\right]$ for $X \in \{K, F\}$ and $y \in \{k, f\}$.

In the terminology thus defined, the "Complementarity-Condition" (A-10) becomes

$$\alpha_k^F > 0. \tag{A-12}$$

Moreover, setting $X = K, F$ and $Y = M$ in inequality (A-7) and using the system (A-11) translates into the following condition

$$\alpha_x^X < 0 \qquad \text{for} \;\; (X, x) \in \{(K, k), (F, f)\}. \tag{A-13}$$

Finally, setting $X = M$ and $Y = K, F$ in inequality (A-7) and using (A-11) leads to[46]

$$-\alpha_k^Y - \alpha_f^Y > 0 \qquad Y = K, F. \tag{A-14}$$

Together, these conditions imply that the determinant of the 2×2 matrix from (A-11) is positive

[46]Notice that, by definition of $k = K/M$ and $f = F/M$, a one percent increase in M is equivalent to a simultaneous one percent decrease in k and f.

Lemma A.2

$$D = \alpha_k^K \alpha_f^F - \alpha_f^K \alpha_k^F > 0.$$

Proof. Consider the two cases $\alpha_f^K < 0$ and $\alpha_f^K > 0$. Case I: if $\alpha_f^K < 0$ this statement is true by (A-12) and (A-13) above.

Case II: if $\alpha_f^K > 0$, instead, (A-14) with $Y = K$ implies $-\alpha_k^K > \alpha_f^K > 0$. Hence, $-\alpha_k^K \alpha_f^F < \alpha_f^K \alpha_f^F$ since $\alpha_f^F < 0$ by (A-13). This implies for the determinant in (A-11)

$$\alpha_k^K \alpha_f^F - \alpha_f^K \alpha_k^F > -\alpha_f^K \alpha_f^F - \alpha_f^K \alpha_k^F = \alpha_f^K(-\alpha_f^F - \alpha_k^F) > 0$$

where the last step follows by $\alpha_f^K > 0$ and (A-14). ■

We can thus invert the system (A-11), writing

$$\begin{pmatrix} \hat{k} \\ \hat{f} \end{pmatrix} = \begin{pmatrix} \sigma_K^k & \sigma_F^k \\ \sigma_K^f & \sigma_F^f \end{pmatrix} \begin{pmatrix} \Delta \hat{w}_K \\ \Delta \hat{w}_F \end{pmatrix} \tag{A-15}$$

According to Cramer's rule, $\sigma_K^k = \alpha_f^F / D$, $\sigma_F^f = \alpha_k^K / D$, $\sigma_F^k = -\alpha_f^K / D$ and $\sigma_K^f = -\alpha_k^F / D$ hold so that the above inequalities on the α_y^X are

$$\sigma_K^f < 0 \quad \text{and} \quad \sigma_Y^y < 0 \quad \text{and} \quad |\sigma_Y^y| > |\sigma_X^y| \quad (Y, X = K, F; \quad X \neq Y). \tag{A-16}$$

By definition, σ_X^y is the economy-wide elasticity of relative demand with respect to the relative factor price, i.e.

$$\sigma_X^y = \frac{(w_X / w_M)}{y} \frac{dy}{d\,(w_X / w_M)} \qquad X = K, F \quad y = k, f. \tag{A-17}$$

Hence the first of the inequalities in (A-16) constitutes the "Complementarity-Condition" (A-10) expressed in terms of factor demand elasticities. The translation into factor price elasticities shows that the "Complementarity-Condition" is equivalent to a relatively strong economy-wide complementarity between capital and female labor ($\sigma_K^f < 0$). For a better understanding of the equivalence between (A-10) and (A-16), observe that, as more capital K is added to the system, demand for female labor F must rise so as to increase its factor reward relative to M. This rise in demand for female labor F is achieved by a strong complementarity between F and K.

A.2.3 Capital Intensity

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

Lemma A.3 *If (A-2), (A-3) and (A-10) hold and $Z^*(\bar{Z})$, is interior, then*

$$K_1/\bar{K} > F_1/\bar{F} \tag{A-18}$$

Proof. As the solution to (A-6) is interior, we can write $w_X = p_1 G_X^1$ ($X = K, M, F$). Observe that the uniqueness of the solution to (A-6), together with homogeneity of degree one of G^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 $\xi = Z^* - \gamma\left(\bar{Z} - Z^*\right)$ for all $\gamma \in \mathbb{R}$. The particular choice $\gamma = F_1/(\bar{F} - F_1)$ implies $\xi = (\xi_1, 0, \xi_3)$. Hence,

$$\left(\xi_1 \frac{d}{d\bar{K}} + \xi_3 \frac{d}{d\bar{M}}\right) \ln\left(\frac{G_F^1(Z^*)}{G_M^1(Z^*)}\right) = 0$$

holds. Therefore, by (A-7) with $X = M$ and $Y = F$ and (A-10), we infer that ξ_1 and ξ_3 have opposite sign. By (A-3) we have

$$\xi_3 = M_1 - (\bar{M} - M_1)F_1/(\bar{F} - F_1) < 0.$$

Therefore, $\xi_1 = K_1 - (\bar{K} - K_1)F_1/(\bar{F} - F_1) > 0$ holds, implying (A-18). ■

The lemma shows that Q_1-production is relatively more K-intensive than F-intensive. Together with (A-3) we then have

$$\frac{K_1}{\bar{K} - K_1} > \frac{F_1}{\bar{F} - F_1} > \frac{M_1}{\bar{M} - M_1} \tag{A-19}$$

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 (A-18), while (A-3) still implied that X_1-production is F-intensive. Under these assumptions, increases in the capital stock would spur production of the X_2-sector.[47] 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 (A-10). – 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.

A.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 that factors are inelastically supplied. We start by introducing the notation a_{Xj} for the (equilibrium) input requirement of factor $X = K, F, M$ to produce one unit of good $j = 1, 2$.

[47]Hence, a Rybczynski-like effect is implicitly assumed to operate. The Rybczynski efffect is dual to the Stolper-Samuelson effect, which the present paper shows not to be holding for male and female labor. Notice that the fact that a Rybczynski-like efffect operates for capital is no contradiction to the key point of the paper.

With this notation, inequalities (A-19) become

$$\frac{a_{K1}}{a_{K2}} > \frac{a_{F1}}{a_{F2}} > \frac{a_{M1}}{a_{M2}}$$

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

$$\frac{\theta_{K1}}{\theta_{K2}} > \frac{\theta_{F1}}{\theta_{F2}} > \frac{\theta_{M1}}{\theta_{M2}} \tag{A-20}$$

In a competitive economy with constant returns to scale

$$\sum\nolimits_X a_{Xj} w_X = p_j \qquad j = 1, 2 \tag{A-21}$$

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 (A-21) with respect to p_i, we apply the envelope theorem to cost minimization (taking partial derivatives of w_X only), which leads to

$$\sum\nolimits_X \theta_{Xj} \hat{w}_X = \delta_{ij} \qquad j = 1, 2 \tag{A-22}$$

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 (A-15) reads

$$\sigma_K^f \left(\hat{w}_K - \hat{w}_M\right) + \sigma_F^f \left(\hat{w}_F - \hat{w}_M\right) = \hat{f}. \tag{A-23}$$

Combining now (A-22) and (A-23) leads to

$$\begin{pmatrix} \theta_{K1} & \theta_{F1} & \theta_{M1} \\ \theta_{K2} & \theta_{F2} & \theta_{M2} \\ \sigma_K^f & \sigma_F^f & -\sigma_K^f - \sigma_F^f \end{pmatrix} \begin{pmatrix} \hat{w}_K \\ \hat{w}_F \\ \hat{w}_M \end{pmatrix} = \begin{pmatrix} \hat{p}_1 \\ \hat{p}_2 \\ \hat{f} \end{pmatrix} \tag{A-24}$$

We will now analyze a one percentage increase in p_1 at constant factor supply. To this aim, consider the exogenous change $(\hat{p}_1, \hat{p}_2, \hat{f})^t = (1, 0, 0)^t$ in (A-24). To solve this specific system, denote the determinant of the 3×3 matrix by Δ and use Cramer's Rule to compute (setting $\sigma_M^f \equiv -\sigma_K^f - \sigma_F^f$)

$$\begin{aligned}
\hat{w}_K &= \Delta^{-1} \det \begin{pmatrix} 1 & \theta_{F1} & \theta_{M1} \\ 0 & \theta_{F2} & \theta_{M2} \\ 0 & \sigma_F^f & \sigma_M^f \end{pmatrix} = \Delta^{-1} \left[\sigma_M^f \theta_{F2} - \sigma_F^f \theta_{M2} \right] \\
\hat{w}_F &= \Delta^{-1} \det \begin{pmatrix} \theta_{K1} & 1 & \theta_{M1} \\ \theta_{K2} & 0 & \theta_{M2} \\ \sigma_K^f & 0 & \sigma_M^f \end{pmatrix} = -\Delta^{-1} \left[\sigma_M^f \theta_{K2} - \sigma_K^f \theta_{M2} \right] \\
\hat{w}_M &= \Delta^{-1} \det \begin{pmatrix} \theta_{K1} & \theta_{F1} & 1 \\ \theta_{K2} & \theta_{F2} & 0 \\ \sigma_K^f & \sigma_F^f & 0 \end{pmatrix} = \Delta^{-1} \left[\sigma_F^f \theta_{K2} - \sigma_K^f \theta_{F2} \right]
\end{aligned}$$

Using $\sum_X \theta_{Xj} = 1$ and $\sum_X \sigma_X^f = 0$ (from $\sigma_M^f \equiv -\sigma_K^f - \sigma_F^f$) leads to

$$\begin{aligned}
\hat{w}_K &= -\Delta^{-1} \left[\sigma_K^f \theta_{F2} + \sigma_F^f (1 - \theta_{K2}) \right] \\
\hat{w}_F &= \Delta^{-1} \left[\sigma_F^f \theta_{K2} + \sigma_K^f (1 - \theta_{F2}) \right] \\
\hat{w}_M &= \Delta^{-1} \left[\sigma_F^f \theta_{K2} - \sigma_K^f \theta_{F2} \right]
\end{aligned} \tag{A-25}$$

Employ again $\sum_X \theta_{Xj} = 1$ and $\sum_X \sigma_X^f = 0$ to compute the determinant Δ:

$$\Delta = \det \begin{pmatrix} \theta_{K1} & 1 & \theta_{M1} \\ \theta_{K2} & 1 & \theta_{M2} \\ \sigma_K^f & 0 & -(\sigma_K^f + \sigma_F^f) \end{pmatrix} = (\theta_{M2} - \theta_{M1})\,\sigma_K^K - (\theta_{K1} - \theta_{K2})\,(\sigma_K^K + \sigma_F^K) \qquad \text{(A-26)}$$

Combining (A-25) and (A-26) leads to

$$\frac{d}{dp_1} \ln\left(\frac{w_F}{w_M}\right) = \frac{\sigma_K^f}{(\theta_{F1} - \theta_{F2})\,\sigma_K^f - (\theta_{K1} - \theta_{K2})\,\sigma_F^f} \qquad \text{(A-27)}$$

This identity implies that female relative wages w_F/w_M are decreasing in p_1 if and only if the expression on the right is negative. Now, using (A-20) together with $\sum_X \theta_{Xj} = 1$, implies $\theta_{K1} > \theta_{K2}$. Since further $\sigma_K^f < 0$ holds by (A-16), we can state that a necessary and sufficient condition for the expression above to be negative is

$$\frac{\theta_{F1} - \theta_{F2}}{\theta_{K1} - \theta_{K2}} \leq \frac{\sigma_F^f}{\sigma_K^f}$$

Finally, the condition formulated in (A-16) implies that the expression on the right exceeds one, while the expression on the left falls short of unity, by (A-20). This proves the following statement.

Proposition A.1 *If (A-10) holds, then*

$$\frac{d}{dp_1} \ln\left(\frac{w_F}{w_M}\right) < 0$$

The proposition shows that, under the "Complementarity-Condition" (A-10) the intuition based on the Stolper-Samuelson effect of a two-good two-factor economy *never* generalizes to F and M in the current setting. Any price increase of the good whose production uses F more intensively than M, decreases the reward for F relative to that of M.

The key condition, of course, is the "Complementarity-Condition". In absence of it, the usual Stolper-Samuelson based intuition concerning the interplay of factor intensities, international specialization and relative factor prices may go through.

A.3 Elastic F-Supply

It is now quick to translate these findings to a framework with elastic F-supply. The ratio of female wage over male wage is G_F^1/G_M^1. Therefore, the supply of female labor over male labor R^s from (A-5) is a function of relative factor prices $\omega = w_F/w_M = G_F^i/G_M^i$. As we have assumed above, the function $R^s(\omega)$ is increasing (see (A-5) in subsection A.1.3).

Turning now to the demand for F, we maintain the assumption that the factors K and M are in inelastic supply. Thus, applying (A-7), we infer that an increase in $\bar{F}$ lowers the ratio of factor prices $\omega = w_F/w_M$. Inverting this relation implies that demand for $\bar{F}$, denoted by $R^d(\omega)$, is a decreasing function of ω.

The functions R^s and R^d are plotted in Figure 5 as solid lines – R^s as an increasing function and R^d as a decreasing function of ω. The figure also depicts the effects of an increase in p_1, which, by Proposition 2, decreases the ratio w_F/w_M for any given level of $\bar{F}$. 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 F drops from F^* to F^{**}.

Lemma A.4 *If (A-10) holds, female labor shares drop whenever p_1/p_2 rises.*

The statement of lemma A.4 reformulates our main result from Proposition A.1. To further translate it to the terminology of trade theory, we spell it out in terms international specialization.

A.4 International Specialization

Up to this stage, we have considered exogenous price changes and their consequence for a small open economy. In the following paragraphs, we will analyze the patterns of specialization that arise in equilibrium and their effect on female labor force participation.

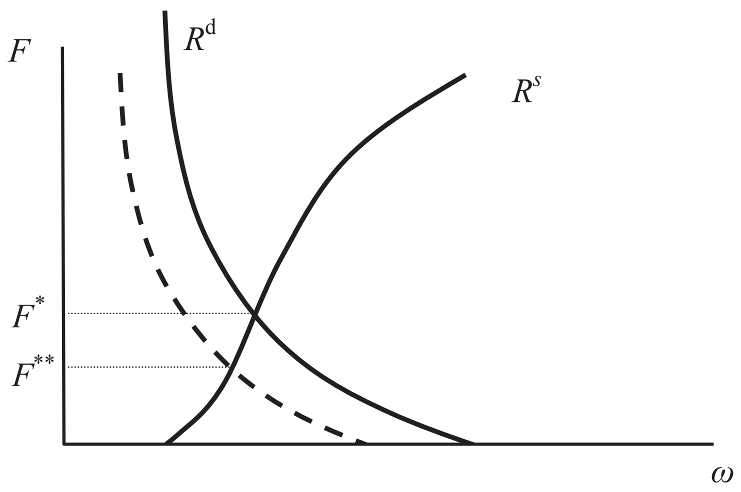


Figure 5: F-type labor - demand and supply.

Nevertheless, we refrain from explicitly solving the general equilibrium of a world economy of many countries instead. Specifically, we assume that the world economy consists of a collection of countries of the type described above. We keep being general in terms of technologies and preferences over consumption goods, assuming that each country faces a set of production technologies (A-1) with which to produce the two consumption goods and individuals have preferences that give rise to F-supply (A-5). We do not require technologies or preferences to be identical across countries. This implies that international specialization may be driven by differences in technologies, 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 "Complementarity-Condition" (A-10) 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, the statement of Lemma A.4 can be reformulated as follows: *given that the "Complementarity-Condition" (A-10) holds, female labor shares* *drop in countries that intensify specialization on sectors intensive in female labor.*

Notice that this statement holds, 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 of 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.