Gender Education Gap and Skill-Biased Structural Change

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Abstract. This paper investigates the role of economic development in narrowing the gender education gap across countries. Using household surveys covering 84 countries from all income levels, we highlight that the gender education gap shrinks with development, while the female labor force share within agriculture declines and that within service increases. Based on these facts, we build a three-sector model in which economic development features skill-biased technological change within sectors and structural transformation. Given women's comparative advantage in services, both forces lead to a higher demand for skilled women, which endogenously increases women's educational attainment. We then parameterize the model to study the quantitative contributions of (1) structural transformation and (2) sector-specific skill-biased technological change in explaining the narrowing gender education gap across countries.

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1 Introduction

A broad panel of advanced economies show narrowing gender employment, wage, and education gaps in the last decades. These observations have generated a vast literature studying the characteristics and consequences of the rise in women's involvement in the labor market. Recently, a few studies have also explored these gender gaps across countries (see, e.g., Olivetti and Petrongolo, 2014; Bento et al., 2021; Bridgman et al., 2018). However, the economic causes of the narrowing gender education gap have remained understudied.

In this paper, we propose two main mechanisms to explain the shrinking gender education gap with development: 1) the structural transformation leading to a rise in services in which women have comparative advantages, thus increasing the relative labor demand of women; 2) skill-biased technological progress within sectors, particularly within services, which further increases the relative demand for skilled (men and) women. Our emphasize on these two channels is motivated and quantitatively tested by the facts that we document using nationally representative data from 257 country-year samples, covering 84 countries from all income levels.

We start by documenting three novel facts across countries. Firstly, in low-income countries, only three out of 100 women complete university education on average, while men are 50% more likely than women to do so. We show that the gender gap in education narrows with development and even reverses in high-income economies, with women on average becoming more educated than men. Secondly, we find that the labor force participation rate of educated women increases modestly with development, while that of low-educated women is U-shaped. Lastly, as the female labor force share in agriculture decreases with development from around 50% to one third, female intensity in services increases, while the female share in the manufacturing sector remains fairly flat and below one third. These trends highlight the importance of two factors to narrow the gender education gap: (1) the expansion of the service sector with economic development and (2) the selection of women in services.

Motivated by these facts, this paper studies the role of economic development on narrowing the gender education gap. We develop a general equilibrium model featuring skill-biased structural transformation, building on the frameworks proposed by Kongsamut et al. (2001), Ngai and Pissarides (2007), Ngai and Petrongolo (2017), Rendall (2018b), and Buera et al. (2021). Female and male agents are heterogeneous in their cost of obtaining education as in Rendall (2018a). Agents choose consumption to maximize their utility subject to their budget constraints. Income is a function of their education and labor force participation decisions: educated workers earn a gender-specific wage premium in equilibrium and those not in the labor force enjoy more home production goods by construction.

On the production side, there are three types of firms, using technologies with different skill and gender intensities to produce agriculture, manufacturing and service goods, respectively. The production of each type of firms is modeled as an aggregate constant elasticity of substitution (CES) production function of high- and low-educational labor, and each education type of labor has a CES production function of female and male labor inputs. Across economies with different development levels, firms face skill-biased technological change and structural transformation simultaneously.

Our calibration strategy is to discipline the model mostly by the U.S. time series data. We first study the quantitative contributions of (1) structural transformation and (2) sector-specific skill-biased technological change in explaining the converging gender education gap in the US. To understand cross-country patterns across the economic development spectrum, we then allow for skill-biased structural transformation across countries and decompose the quantitative effects of the two described mechanisms on narrowing the gender education gap.

Related Literature. Our paper is most related to the existing literature that seeks to understand the causes of the decline in the gender education gap with development. To explain the patterns in the U.S., Rıos-Rull and Sanchez-Marcos (2002) emphasize the fertility cost of women going to college relative to men; and Rendall (2018a) emphasizes the demand shift from physical to intellectual skills. More recent work by Reimers (2020) studies the role of structural transformation on women's relative education and formal hours, but abstracts from the role of skill-biased technological change.

Our work also builds on the the growing literature on structural change (Herrendorf et al., 2014). One close paper to our work is Buera et al. (2021), who study how skill-biased structural transformation can explain the college premium. In addition, our paper relates to the literature trying to understand the link between structural transformation and cross-country patterns of labor market outcomes (see e.g., Duarte and Restuccia, 2010; Ngai et al., 2020; Feng et al., 2020; Porzio et al., 2020). However, none of these studies focuses on the the driving forces of narrowing the gender education gap.

2 Data and Empirical Findings

In this section, we present empirical findings on individual-level education and labor supply choices across countries. We show three robust patterns with development, both across countries and within a country over time: (1) the gender gap in education narrows with development; (2) the labor force participation rate (LFPR) of high-educated women modestly increases with development, while that of the low-educated women is U-shaped. In contrast, men's LFPR remains high across all development levels; (3) women's share within the service labor force increases strongly with economic growth.

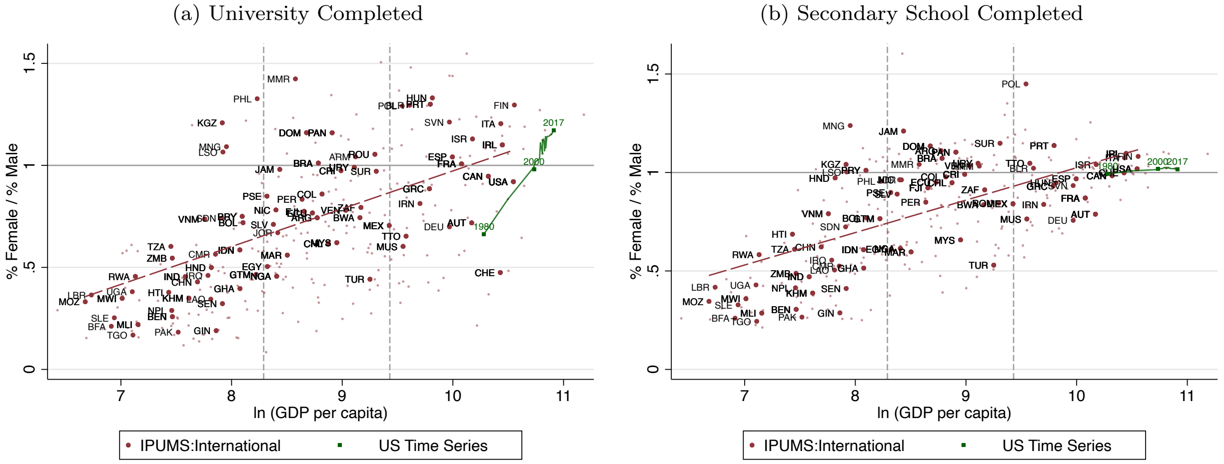
Data. For the cross-country analysis, we draw on the household censuses and surveys from *IPUMS International*, which includes individual level information on age, gender, educational attainment, employment status, and industry. The data set ranges from 1960 to 2014 and covers 256 country-year censuses and surveys across 84 countries from all income levels. We also look into the U.S. time-series patterns using data from IPUMS: USA from the year 1980 to 2017, which is the period where most of the structural transformation towards services takes place in the US. Lastly, for estimates of GDP per capita, we use output-side real GDP at chained PPPs in 2011 US$ (rgdpo) from the Penn World Table version 9.1 (PWT 9.1).

In our analysis, we restrict attention to prime-aged (aged 25-54) men and women. We also require information on employment status and industry. Hence, we exclude those with missing values of these key variables and those living in group quarters. In addition, we use sample weights whenever they are available.

Fact 1: The gender education gap. We define the gender gap in education as the ratio of the share of females who have completed university/secondary school to that of males. Figure 1 plots the gender gaps in university completion and secondary school completion against log GDP per capita in Panel (a) and (b), respectively.

Figure 1: Gender Gap in Education

(a) University Completed   (b) Secondary School Completed



Note: This figure plots the female-to-male population shares of completing university/secondary school against log GDP per capita for each country-year sample (light red dot) and the country averages (dark red dot). Green data points show the US time trends. We combine the source data from IPUMS International and IPUMS:USA.

Panel (a) of Figure 1 highlights that, in the poorest economies, women are more than 50% less likely to obtain a college degree compared to their male counterparts. This gender education gap narrows quickly with development levels. In addition, the cross-country patterns are broadly consistent with the U.S. time series data: the gender gap appears to be large in the 1980, but steadily decreases, reaches equality in the 1990s; since then, the share of women with completed university education has been larger than the share of men. Furthermore, the patterns of the gender gap in completing secondary school with development are similar to that in completing university, as shown in Panel (b) of Figure 1.

Table 1: Regressions of Gender Gap in Education with Development

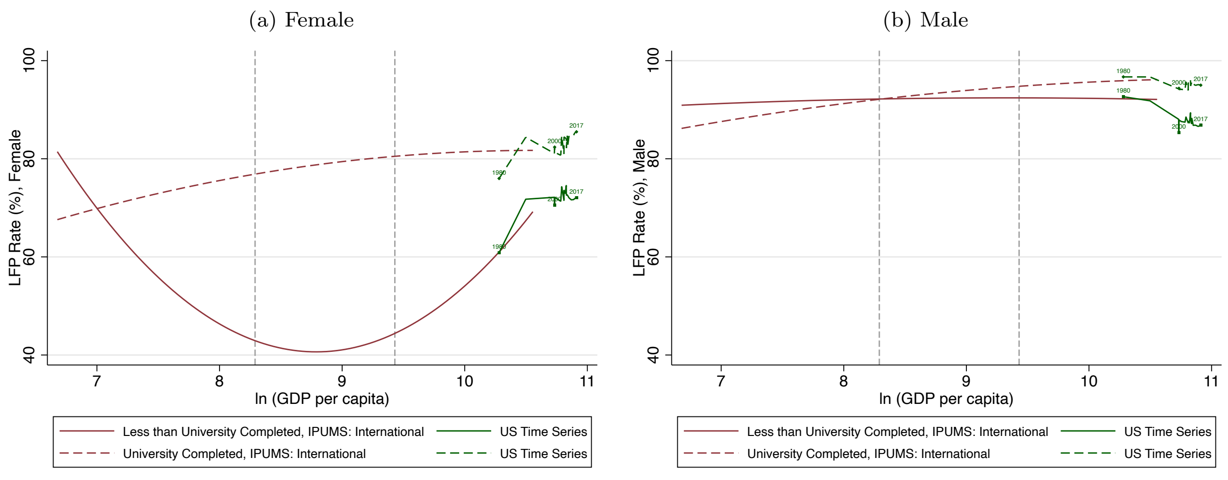
	By University		By Secondary	
	Country-year	Country-average	Country-year	Country-average
ln (GDP per capita)	0.21***	0.21***	0.18***	0.19***
	(0.014)	(0.025)	(0.010)	(0.019)
R^2	0.38	0.44	0.43	0.47
Obs.	257	84	257	84

Note: The gender gap is defined as the share of females who complete university/secondary school divide by that of males. *** indicates statistical significance at the 1-percent level. Standard errors are given in parentheses.

Table 1 further reports the slope coefficients of the ratio of women's to men's share of completing university/secondary school on log GDP per capita using various alternative cuts of the data. We first use the shares of university completion by gender to measure the gender gap. When considering all 257 country-year surveys separately, the slope is 0.21, which is the same as for country averages shown in Figure 1. We then use the shares of completing secondary school, the slope coefficient becomes 0.18 and 0.19 for the country-year and country-average regressions, respectively. All four slopes are statistically significant at the one percent level. We conclude that the pattern of decreasing gender gap and its magnitudes are very robust.

Fact 2: The LFPR. We now turn to the labor force participation rate by gender and by education attainment. We use the employment status variable (*empstat*) to classify all employed and unemployed individuals as in the labor force, and all others as not in the labor force. As shown in Figure 2, the LFPR of women who have completed university modestly increases with development from around 70% to 80%, and that of women who did not complete university is U-shaped. The pattern of aggregate female LFPR is dominated by that of the low-educated, resulting in an average LFPR of 55%, 47%, and 65%, respectively, for countries with available data in the bottom, middle, and top terciles of the world income distribution.[1] In contrast, men's LFPR remains high for both education groups throughout development. In particular, the aggregate males LFPR is 90%, 92%, and 92%, respectively, for the three terciles of world income distribution.

Figure 2: Labor Force Participation Rate (%) by Gender and Education



Note: Red lines represent quadratic fitted lines of country-average labor force participation rates against log GDP per capita by gender and education.

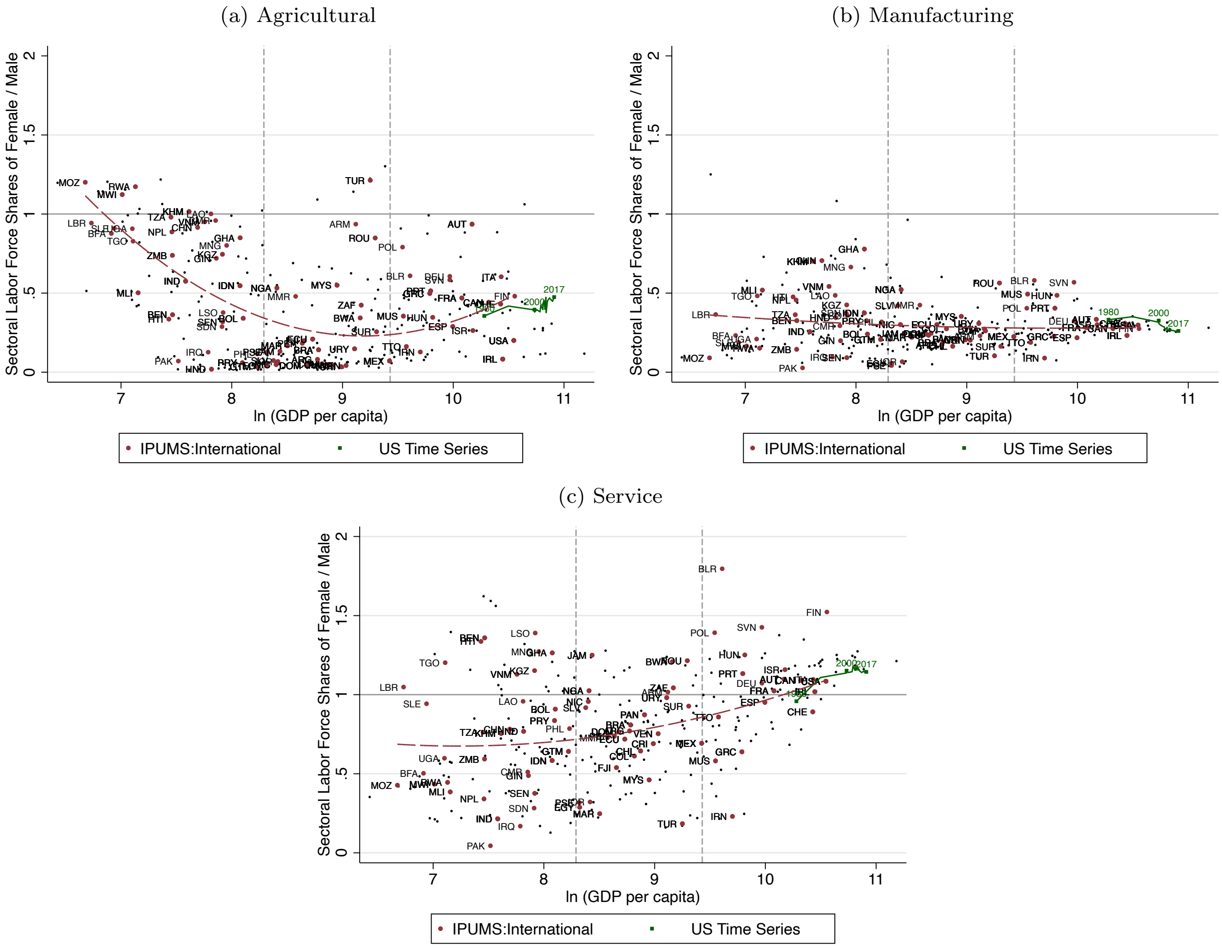
Fact 3: The gender labor shares by sector. To further understand the link between the rise in women's education attainment and structural transformation, we study the ratio of female-to-male labor force shares within agriculture, manufacturing, and service sectors, respectively, based on the industry variable (*indgen*).[2] To control for potential differences in the gender population sizes and facilitate the comparisons between data and the model, within each country-year sample, we first normalize both the female and male population sizes to be one, and then take the ratio of the number of female workers to that of male workers in the same sector. We interpret this ratio as a measure of the sector-specific

[1] The intervals for low- (bottom third of the world's income distribution), middle- (middle third), and high-income (top third) countries are $\leq$ \$3,979, between \$3,980 and \$12,449, and $\geq$ \$12,450 based on country-average GDP per capita from 1960 to 2017 for all countries in the PWT 9.1. These thresholds are close to the thresholds for lower middle-, upper-middle- and high-income countries from the World Bank.

[2] The agriculture sector includes agriculture, fishing, and forestry; the "manufacturing, etc." sector includes manufacturing, construction, mining, utilities; the service sector includes wholesale and retail trade, hotels and restaurants, transportation, storage, and communications, financial services and insurance, services not specified, business services and real estate, education, health and social work, other services, and private household services.

"female-intensity".

Figure 3: Gender Gaps in Labor Force Shares, by Sector



Note: This figure plots the ratios of female-to-male labor force shares within agriculture, manufacturing, and services against log GDP per capita for each country-year sample (light red dot) and the country averages (dark red dot). Green data shows the US time trends. We combine the source data from IPUMS International and IPUMS:USA.

Figure 3 plots the female intensity by sector across countries and over time in the US. We find that, as the development level increases across countries, the agricultural sector becomes much less intensive in female labor, with the ratio decreasing from 1 to less than 0.5. On the other hand, the service sector becomes more intensive in female labor, with the labor of women surpassing that of men, while the manufacturing sector remains the least intensive in female labor, with an average ratio of around 0.4 throughout different development levels.

To sum it up, this section describes the patterns of education attainment, labor force participation, and the rise of women's involvement in service sector with development. They highlight the importance of considering skill-biased structural transformation when one aims to understand the narrowing education gap.

3 The model

This section introduces our benchmark general equilibrium model with endogenous education and labor supply decisions. In our setup, large agricultural sectors in poor economies can be generated by either income effects or differential productivity growth rates.

3.1 Environment

There is a mass one of females and males, respectively, differentiated by their cost of study $(a) \in \mathbb{R}_+$. Let $\Gamma(a)$ denote the distribution of (a). Individuals face a discrete education choice: to obtain education or not. Those choosing an education must pay a utility cost $g(a)$, which is increasing in a. Education has no value in agriculture. Individuals also face a discrete occupation choice: to work in an agricultural B, goods, G, or service S occupation. Individuals, if working, supply one unit to the labor market.

Let $\mathbb{O} = \{NS, ES, NG, EG, NB\}$ describe the set of education-occupation possibilities. Note, by assumption education has no value in the agricultural sector. Wages will equal across sectors as we assume free mobility across sectors.

Education decisions. Suppose the expected utility functions of completing and not completing university/secondary school are $\mathbb{E}_E^g(U(c, c_H)) - g(a)$ and $\mathbb{E}_N^g(U(c, c_H))$, respectively. Hence, an individual with an education cost of a will obtain education if and only if $a < \mathbb{E}_E^g(U(c, c_H)) - \mathbb{E}_N^g(U(c, c_H))$.

Households' consumption. Each household (j, j') is composed of one man and one woman where the male's education is j and the female's education is j'. As we focus on the extensive margin of labor supply and study economies across development levels, we allow home production to substitute all food, goods, and services in the benchmark model.[3]

The household's market consumption is a CES of,

$$c = \left(\phi_G c_G^{\frac{\nu-1}{\nu}} + \phi_S c_S^{\frac{\nu-1}{\nu}} + \phi_B (c_B - \underline{B})^{\frac{\nu-1}{\nu}}\right)^{\frac{\nu}{\nu-1}} \tag{1}$$

where c_G, c_S and c_B are sector-specific consumption, $\underline{B}$ is a constant subsistence level of consumption, and ν is the elasticity of substitution between consumption of all sectors. We

[3] Ngai and Pissarides (2008) argue that, with technological progress, home production of food and goods disappears and only home production of services remains. In Appendix B, we allow for a nested CES where only services are substitutable to home production, as commonly assumed in the literature.

assume males inelastically supply one unit of labor. We assume home production, c_H, is only produced by women and takes a value drawn from the distribution $x \sim N_j(\bar{H}, \sigma_H^2), j = E, N$. The household consumes $c_H = x$ if the female does not work in the market, but takes $c_H = 0$ if she does work in the market. Households maximise,

$$\max_{c_G, c_S, c_B, c_H, l^f} U(c, c_H) \tag{2}$$

s.t.

$$\sum_{i=G,S,B} p_i c_i \leq w_j^m + w_{j'}^f l_{jj'}^f \equiv y_{jj'W} \tag{3}$$

where p_i denotes the goods price of sector $i = G, S, B$, w_j^m and $w_{j'}^f$ denote the wage income for the man and the women, respectively, and $l_{jj'}^f = 1$ if the woman works and zero otherwise. We set $W = l_{jj'}^f$ to be the index of whether the female works in the market for a household type (j, j').

Given market income, agents maximise market consumption c. That is, we can ignore the home production choice and solve consumption conditional on income, $y_{jj'W}$. Let $\Omega = p_S \left(\frac{\phi_s}{p_s}\right)^\nu + p_B \left(\frac{\phi_B}{p_B}\right)^\nu + p_G \left(\frac{\phi_G}{p_G}\right)^\nu$, which we can interpret as the aggregate price index of the consumer. Then we can solve for the market consumption as,

$$c_{jj'W} = (y_{jj'W} - p_B \underline{B}) (\Omega)^{\frac{1}{\nu-1}}, \tag{4}$$

The discrete choice of entering the labor market or not for females is,

$$U(c_{jj'1}, 0) \geq U(c_{jj'0}, x) \tag{5}$$

If market and home are perfect substitutes, $U(c, c_H) = (c + c_H)$, Equation (5) becomes $w_j^f \geq \Omega^{\frac{-1}{\nu-1}} x \equiv \underline{w}_j^f(x)$. Thus, women's employment choices are independent of male wages, as long as male wages over the subsistence level in agricultural goods. Suppose market and home consumption are imperfect substitutes, $U(c, c_H) = \left(c^{\frac{\sigma-1}{\sigma}} + c_H^{\frac{\sigma-1}{\sigma}}\right)^{\frac{\sigma}{\sigma-1}}$, Equation (5) becomes,

$$\left(\Omega^{\frac{1}{\nu-1}}\right)^{\frac{\sigma-1}{\sigma}} \left[\left(w_j^f + w_j^m - p_B \underline{B}\right)^{\frac{\sigma-1}{\sigma}} - \left(w_j^m - p_B \underline{B}\right)^{\frac{\sigma-1}{\sigma}}\right] \geq x^{\frac{\sigma-1}{\sigma}},$$

$$w_j^f \geq \left[\left(\Omega^{\frac{1}{\nu-1}}\right)^{-\frac{\sigma-1}{\sigma}} x^{\frac{\sigma-1}{\sigma}} + \left(w_j^m - p_B \underline{B}\right)^{\frac{\sigma-1}{\sigma}}\right]^{\frac{\sigma}{\sigma-1}} - \left(w_j^m - p_B \underline{B}\right) \equiv \underline{w}_j^f(x, w_j^m). \tag{6}$$

Females also work if

$$w_j^m < p_B \underline{B}. \tag{7}$$

That is, males wages do not cover the subsistence requirement in agricultural goods.

Denote $\underline{x}_j^f$ as the cutoff of home production such that $\underline{w}_j^f(\underline{x}_j^f) = w_j^f$. Set $\underline{x}_j^f \to +\infty$ if $w_j^m < p_B \underline{B}$. Therefore, the share of women not in labor force participation by education group are given by

$$NL_E^f = \left(1 - N_E(\underline{x}_E^f)\right) \Gamma(a^{*f}) \tag{8}$$

$$NL_N^f = \left(1 - N_N(\underline{x}_N^f)\right) \left(1 - \Gamma(a^{*f})\right). \tag{9}$$

3.2 Firms' production

The production functions for all three market sectors are,

$$Y_k = A_k H_k, \text{ for } k = G, S, B,$$

where output is a CES of educated and uneducated labor in goods and services

$$H_k = \left(\chi_k H_{Ek}^{\frac{\theta-1}{\theta}} + (1-\chi_k) H_{Nk}^{\frac{\theta-1}{\theta}}\right)^{\frac{\theta}{\theta-1}}, \text{ for } k = G, S.$$

$$H_B = H_{NB}.$$

with each labor input being a CES of men and women, in all three sector, $k = G, S, B$

$$H_{jk} = F\left(H_{jk}^f, H_{jk}^m\right)$$

$$= \left(\zeta_{jk}(H_{jk}^f)^{\frac{\eta-1}{\eta}} + (1-\zeta_{jk})(H_{jk}^m)^{\frac{\eta-1}{\eta}}\right)^{\frac{\eta}{\eta-1}}.$$

Further, we define total labor force participation for gender g and education j by,

$$H_j^g = \sum_k H_{jk}^g. \tag{10}$$

Since labor is perfectly mobile across sectors but not education, and each firm's objective is to maximize profit, the firms problem is,

$$\max_{\{H_{jk}^g\}} p_k Y_k - \sum_{jg} w_j^g H_{jk}^g.$$

Labor are paid their marginal products. In equilibrium $w_{Ek}^f = w_E^f$, $w_{Nk}^f = w_N^f$, $w_{Ek}^m = w_E^m$ and $w_{Nk}^m = w_N^m$. Therefore, we can solve for the gender wage gaps by education:

$$x_j = \frac{w_j^f}{w_j^m} = \frac{\zeta_{jk}}{1-\zeta_{jk}} \left(\frac{H_{jk}^f}{H_{jk}^m} \right)^{-\frac{1}{\eta}}, j = E, N. \tag{11}$$

In addition, the college wage premium if given by:

$$\pi^f = \frac{w_E^f}{w_N^f} = \pi_k \frac{\zeta_{Ek}}{\zeta_{Nk}} \left(\frac{H_{Ek}}{H_{Ek}^f} \frac{H_{Nk}^f}{H_{Nk}} \right)^{\frac{1}{\eta}}, \text{ where} \tag{12}$$

$$\pi_k = \frac{p_{Ek}}{p_{Nk}} = \frac{\chi_k}{1-\chi_k} \left(\frac{H_{Ek}}{H_{Nk}} \right)^{-\frac{1}{\theta}}, k = G, S \tag{13}$$

3.3 Equilibrium Definition

A competitive equilibrium is defined by education choices (a^{*m}, a^{*f}), market wages $(w_N^m, w_E^m, w_N^f, w_E^f)$, market prices (p_G, p_S, p_B), consumption $\{c_{jj'WB}, c_{jj'WG}, c_{jj'WS}, , c_{jj'WH}\}_{j,j'=E,N;W=0,1}$, labor allocation $\{H_{Ek}^g\}_{g=f,m;k=G,S.}$ and $\{H_{Nk}^g\}_{g=f,m;k=G,S,B.}$, such that:
(i) individuals make optimal education choices where men with $a < a^{*m}$ and women with $a < a^{*f}$ obtain education, while others do not; and females make optimal labor force participation choices where they work if $x > \underline{x}_j^f$;
(ii) the representative firm maximizes profits, subject to technology in Section 3.2; and individuals maximize utility (2), subject to the budget constraint (3);
(iii) given the optimal choices of firms and households, market wages and prices clear the market in each sector and the labor market for each education-gender group:

$$\sum_{jj'=EE,EN,NE,NN;W=0,1} c_{jj'Wk} = Y_k, k = B, G, S; \tag{14}$$

$$H_{EG}^g + H_{ES}^g + NL_E^g = \Gamma(a^{*g}), g = f, m; \tag{15}$$

$$H_{NB}^g + H_{NG}^g + H_{NS}^g + NL_N^g = 1 - \Gamma(a^{*g}), g = f, m. \tag{16}$$

3.4 Model Predictions

We focus on two mechanisms that qualitatively narrow the gender education gap in our model. The first one is the skill-biased technological change within the service sector, or an increase in χ_S. The second one is structural transformation due to a higher growth rate of A_S compared to A_G. The two properties are verified by our simulation results.

4 Quantitative Analysis (In progress)

We have developed a model in which the gender education gap narrows with skill-biased structural transformation. To what extend can our model account for the cross-country patterns is a quantitative question. In this section we calibrate the model to match features of the U.S. economy between year 1980 and 2017. Then we fix all the parameters but allow for exogenous variations in sectoral productivity A_B, A_G, A_S and sectoral skill intensity χ_G, χ_S to match the patterns between key features of the labor markets and development across countries.

4.1 Calibration

5 Conclusion

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Appendices

A Proofs of the theoretical results

A.1 Consumption

Given market income agents maximise market consumption c. That is, we can ignore the home production choice and solve consumption conditional on income, $y_{Wjj'}$. Substituting the budget constraint for c_S, $c_S = \frac{y_{Wjj'} - p_B c_B - p_G c_G}{p_S}$, FOCS are,

$$\frac{\partial c}{\partial c_B} = c^{\frac{1}{\nu}} \left[\phi_B \left(c_B - \underline{B} \right)^{\frac{-1}{\nu}} - \phi_S \left(c_S \right)^{\frac{-1}{\nu}} \frac{p_B}{p_S} \right] = 0 \tag{17}$$

$$\frac{\partial c}{\partial c_G} = c^{\frac{1}{\nu}} \left[\phi_G \left(c_G \right)^{\frac{-1}{\nu}} - \phi_S \left(c_S \right)^{\frac{-1}{\nu}} \frac{p_B}{p_S} \right] = 0 \tag{18}$$

Using the two first order conditions and the budget constraint we can derive the following relative consumption choices and consumption of market services,

$$\frac{c_S}{c_B - \underline{B}} = \left(\frac{\phi_S}{\phi_B} \frac{p_B}{p_S} \right)^{\nu} \tag{19}$$

$$\frac{c_S}{c_G} = \left(\frac{\phi_S}{\phi_G} \frac{p_G}{p_S} \right)^{\nu} \tag{20}$$

$$c_S = \frac{y_j - p_B \underline{B}}{p_S + p_B \left(\frac{\phi_B}{\phi_S} \frac{p_S}{p_B} \right)^{\nu} + p_G \left(\frac{\phi_G}{\phi_S} \frac{p_S}{p_G} \right)^{\nu}} \tag{21}$$

Note, relative consumption, Equations (19) and (20), does not depend on education-occupation status.

Define $\Omega = p_S \left(\frac{\phi_s}{p_s} \right)^{\nu} + p_B \left(\frac{\phi_B}{p_B} \right)^{\nu} + p_G \left(\frac{\phi_G}{p_G} \right)^{\nu}$, given Equations (19)-(21), market consumption is,

$$c_{Wjj'} = \left(y_{jj'} - p_B \underline{B} \right) \left(\Omega \right)^{\frac{1}{\nu - 1}} , \tag{22}$$

where Ω is the aggregate price index of the consumer.

A.2 Production

The marginal products of labor are

$$
\begin{aligned}
w^f_{Ek} &= p_k A_k H_k^{\frac{1}{\theta}} \chi_k H_{Ek}^{-\frac{1}{\theta}+\frac{1}{\eta}} \zeta_{Ek} (H^f_{Ek})^{-\frac{1}{\eta}} \text{ for } k = S, G \\
w^f_{Nk} &= p_k A_k H_k^{\frac{1}{\theta}} (1-\chi_k) H_{Nk}^{-\frac{1}{\theta}+\frac{1}{\eta}} \zeta_{Nk} (H^f_{Nk})^{-\frac{1}{\eta}} \text{ for } k = S, G \\
w^m_{Ek} &= p_k A_k H_k^{\frac{1}{\theta}} \chi_k H_{Ek}^{-\frac{1}{\theta}+\frac{1}{\eta}} (1-\zeta_{Ek}) (H^m_{Ek})^{-\frac{1}{\eta}} \text{ for } k = S, G \\
w^m_{Nk} &= p_k A_k H_k^{\frac{1}{\theta}} (1-\chi_k) H_{Nk}^{-\frac{1}{\theta}+\frac{1}{\eta}} (1-\zeta_{Nk}) (H^m_{Nk})^{-\frac{1}{\eta}} \text{ for } k = S, G \\
w^f_{NB} &= p_B A_B (H_{NB})^{\frac{1}{\eta}} \zeta_{NB} (H^f_{NB})^{-\frac{1}{\eta}} \\
w^m_{NB} &= p_B A_B (H_{NB})^{\frac{1}{\eta}} (1-\zeta_{NB}) (H^m_{NB})^{-\frac{1}{\eta}}
\end{aligned}
\tag{23}
$$

Define wage bill shares by gender as,

$$
I^f_{jk} = \frac{w^f_k H^f_{jk}}{w^f_k H^f_{jk} + w^m_k H^m_{jk}}, \text{ where } j = E, N, \text{ and } k = G, S. \tag{24}
$$

and by education type as,

$$
I_{Ek} = \frac{p_{Ek} H_{Ek}}{p_{Ek} H_{Ek} + p_{Nk} H_{Nk}}, \text{ where } k = G, S. \tag{25}
$$

where $I_{Nk} = 1 - I_{Ek}$ and education-specific factor prices are,

$$
p_{Ek} = p_k A_k H_k^{\frac{1}{\theta}} \chi_k \left(H_{Ek}\right)^{-\frac{1}{\theta}}
$$

$$
p_{Nk} = p_k A_k H_k^{\frac{1}{\theta}} (1-\chi_k) \left(H_{Nk}\right)^{-\frac{1}{\theta}} .
$$

Using (11) and (13) the wage bill shares are,

$$
I^f_{jk} = \left[1 + x_j^{\eta-1} \left(\frac{1-\zeta_{jk}}{\zeta_{jk}}\right)^{\eta}\right]^{-1} \tag{26}
$$

and

$$
I_{Ek} = \left[1 + \pi_k^{\theta-1} \left(\frac{1-\chi_k}{\chi_k}\right)^{\theta}\right]^{-1} \tag{27}
$$

$$
I_{Nk} = 1 - I_{Ek} = \left[\pi_k^{\theta-1} \left(\frac{1-\chi_k}{\chi_k}\right)^{\theta}\right] \left[1 + \pi_k^{\theta-1} \left(\frac{1-\chi_k}{\chi_k}\right)^{\theta}\right]^{-1} \tag{28}
$$

From the above two equations and the production functions, we obtain

$$\frac{H_{jk}}{H^f_{jk}} = \left(\frac{\zeta_{jk}}{I^f_{jk}}\right)^{\frac{\eta}{\eta-1}} \tag{29}$$

$$\frac{H_k}{H_{Ek}} = \left(\frac{\chi_k}{I_{Ek}}\right)^{\frac{\theta}{\theta-1}} \tag{30}$$

and

$$\frac{H_k}{H_{Nk}} = \pi_k^{-\theta}\left(\frac{\chi_k}{1-\chi_k}\right)^{\theta}\left(\frac{\chi_k}{I_{Ek}}\right)^{\frac{\theta}{\theta-1}} = \left(\frac{1-\chi_k}{I_{Nk}}\right)^{\frac{\theta}{\theta-1}} \tag{31}$$

and the output in terms of relative wage bills

$$Y_k = A_k H_{Ek}\left(\frac{\chi_k}{I_{Ek}}\right)^{\frac{\theta}{\theta-1}} \tag{32}$$

$$Y_k = A_k H_{Nk}\left(\frac{1-\chi_k}{I_{Nk}}\right)^{\frac{\theta}{\theta-1}} \tag{33}$$

$$Y_k = A_k H^f_{Ek}\left(\frac{\zeta_{Ek}}{I^f_{Ek}}\right)^{\frac{\eta}{\eta-1}}\left(\frac{\chi_k}{I_{Ek}}\right)^{\frac{\theta}{\theta-1}} \tag{34}$$

$$Y_k = A_k H^f_{Nk}\left(\frac{\zeta_{Nk}}{I^f_{Nk}}\right)^{\frac{\eta}{\eta-1}}\left(\frac{1-\chi_k}{I_{Nk}}\right)^{\frac{\theta}{\theta-1}} \tag{35}$$

Since wages by gender equal across sectors in equilibrium, using marginal products and the above 4 equations, we have

$$\frac{p_S}{p_G} = \frac{A_G}{A_S}\left(\frac{\chi_G}{\chi_S}\right)^{\frac{\theta}{\theta-1}}\left(\frac{\zeta_{EG}}{\zeta_{ES}}\right)^{\frac{\eta}{\eta-1}}\left(\frac{I_{ES}}{I_{EG}}\right)^{\frac{1}{\theta-1}}\left(\frac{I^f_{ES}}{I^f_{EG}}\right)^{\frac{1}{\eta-1}} \tag{36}$$

or

$$\frac{p_S}{p_G} = \frac{A_G}{A_S}\left(\frac{1-\chi_G}{1-\chi_S}\right)^{\frac{\theta}{\theta-1}}\left(\frac{\zeta_{NG}}{\zeta_{NS}}\right)^{\frac{\eta}{\eta-1}}\left(\frac{I_{NS}}{I_{NG}}\right)^{\frac{1}{\theta-1}}\left(\frac{I^f_{NS}}{I^f_{NG}}\right)^{\frac{1}{\eta-1}} \tag{37}$$

and

$$\frac{p_B}{p_S} = \frac{A_S}{A_B}(1-\chi_S)^{\frac{\theta}{\theta-1}}\left(\frac{\zeta_{NS}}{\zeta_{NB}}\right)^{\frac{\eta}{\eta-1}}\left(\frac{1}{I_{NS}}\right)^{\frac{1}{\theta-1}}\left(\frac{I^f_{NB}}{I^f_{NS}}\right)^{\frac{1}{\eta-1}} \tag{38}$$

Using Equation (20) from the consumer problem and relative prices Equations (36) or (37) and output Equations (32) and (34) from the producer problem, and goods market clearing we have,

$$\frac{Y_S}{Y_G} = \left(\frac{\phi_S}{\phi_G}\frac{p_G}{p_S}\right)^{\nu} \tag{39}$$

$$\frac{A_S}{A_G}\frac{H_{ES}}{H_{EG}}\left(\frac{\chi_S}{\chi_G}\right)^{\frac{\theta}{\theta-1}}\left(\frac{I_{EG}}{I_{ES}}\right)^{\frac{\theta}{\theta-1}} = \left(\frac{\phi_S}{\phi_G}\frac{p_G}{p_S}\right)^{\nu} \tag{40}$$

$$\frac{H_{ES}}{H_{EG}} = \frac{A_G}{A_S}\left(\frac{\phi_S}{\phi_G}\frac{p_G}{p_S}\right)^{\nu}\left(\frac{\chi_S}{\chi_G}\right)^{\frac{-\theta}{\theta-1}}\left(\frac{I_{EG}}{I_{ES}}\right)^{\frac{-\theta}{\theta-1}} \tag{41}$$

$$\frac{H_{ES}}{H_{EG}} = \left(\frac{A_G}{A_S}\right)^{1-\nu}\left(\frac{\phi_S}{\phi_G}\right)^{\nu}\left(\frac{\zeta_{ES}}{\zeta_{EG}}\right)^{\frac{\eta\nu}{\eta-1}}\left(\frac{\chi_G}{\chi_S}\right)^{\frac{\theta(1-\nu)}{\theta-1}}\left(\frac{I_{ES}}{I_{EG}}\right)^{\frac{\theta-\nu}{\theta-1}}\left(\frac{I^f_{EG}}{I^f_{ES}}\right)^{\frac{\nu}{\eta-1}} \tag{42}$$

Second, using consumption decisions and market clearing, we can solve again for the equilibrium, but now we need to add agriculture, which includes the non-homotheticity.

$$Y_S = \left(\frac{\phi_S}{\phi_B}\frac{p_B}{p_S}\right)^{\nu}(Y_B - \underline{B}) \tag{43}$$

$$A_S H_{NS}\left(\frac{1-\chi_S}{I_{ES}}\right)^{\frac{\theta}{\theta-1}} = \left(\frac{\phi_S}{\phi_B}\frac{p_B}{p_S}\right)^{\nu}(A_B H_{NB} - \underline{B}) \tag{44}$$

$$A_S H_{NS}\left(\frac{1-\chi_S}{I_{ES}}\right)^{\frac{\theta}{\theta-1}} = \left(\frac{\phi_S}{\phi_B}\frac{A_S}{A_B}(1-\chi_S)^{\frac{\theta}{\theta-1}}\left(\frac{\zeta_{NS}}{\zeta_{NB}}\right)^{\frac{\eta}{\eta-1}}\left(\frac{1}{I_{NS}}\right)^{\frac{1}{\theta-1}}\left(\frac{I^f_{NB}}{I^f_{NS}}\right)^{\frac{1}{\eta-1}}\right)^{\nu} (A_B H_{NB} - \underline{B}) \tag{45}$$

$$A_S H^f_{NS}\left(\frac{\zeta_{NS}}{I^f_{NS}}\right)^{\frac{\eta}{\eta-1}}\left(\frac{1-\chi_S}{I_{ES}}\right)^{\frac{\theta}{\theta-1}} = \left(\frac{\phi_S}{\phi_B}\frac{A_S}{A_B}(1-\chi_S)^{\frac{\theta}{\theta-1}}\left(\frac{\zeta_{NS}}{\zeta_{NB}}\right)^{\frac{\eta}{\eta-1}}\left(\frac{1}{I_{NS}}\right)^{\frac{1}{\theta-1}}\left(\frac{I^f_{NB}}{I^f_{NS}}\right)^{\frac{1}{\eta-1}}\right)^{\nu} \left(A_B H^f_{NB}\left(\frac{\zeta_{NB}}{I^f_{NB}}\right)^{\frac{\eta}{\eta-1}} - \underline{B}\right) \tag{46}$$

Lastly, using the zero profit condition we can solve for prices as function of wage rates. Goods and service prices are,

$$p_k = \frac{1}{A_k}\left\{\chi_k^{\theta} p_{Ek}^{1-\theta} + (1-\chi_k)^{\theta} p_{Nk}^{1-\theta}\right\}^{\frac{-1}{\theta-1}} \tag{47}$$

or equivalently

$$p_k = \frac{1}{A_k}\left\{\chi_k^\theta \left[\zeta_{Ek}^\eta (w_E^f)^{1-\eta} + (1-\zeta_{Ek})^\eta (w_E^m)^{1-\eta}\right]^{\frac{\theta-1}{\eta-1}} \right.$$
$$\left. + (1-\chi_k)^\theta \left[\zeta_{Nk}^\eta (w_N^f)^{1-\eta} + (1-\zeta_{Nk})^\eta (w_N^m)^{1-\eta}\right]^{\frac{\theta-1}{\eta-1}}\right\}^{\frac{-1}{\theta-1}}. \tag{48}$$

and agricultural prices, given the absence of education returns, are,

$$p_B = \frac{1}{A_B}\left\{\zeta_{NB}^\eta (w_N^f)^{1-\eta} + (1-\zeta_{NB})^\eta (w_N^m)^{1-\eta}\right\}^{\frac{-1}{\eta-1}}. \tag{49}$$

B Alternative Model with Service Marketization

In this section, we present an alternative version of the model where home production only substitutes services.

The houehold's aggregate market and home consumption is a CES of,

$$c = \left(\phi_G c_G^{\frac{\nu-1}{\nu}} + \phi_S \hat{c}_S^{\frac{\nu-1}{\nu}} + \phi_B (c_B - \underline{B})^{\frac{\nu-1}{\nu}}\right)^{\frac{\nu}{\nu-1}} \tag{50}$$

where c_G and c_B are sector-specific consumption, $\underline{B}$ is a constant as in the benchmark model. But $\hat{c}_S$ is composite service-consumption made up of home and market consumption. Given the discrete employment choices, service consumption is,

$$\hat{c}_S = \left(c_H^{\frac{\sigma-1}{\sigma}} + c_S^{\frac{\sigma-1}{\sigma}}\right)^{\frac{\sigma}{\sigma-1}}. \tag{51}$$

As in the benchmark, we assume home production, c_H, is only produced by women and takes a value drawn from the distribution $x \sim N_j(\bar{H}, \sigma_H^2), j = E, N$. The household consumes $c_H = x$ if the female does not work in the market, but takes $c_H = 0$ if she does work in the market. Households maximise,

$$\max_{c_G, c_S, c_B, c_H, l^f} U(c, c_H) \tag{52}$$

s.t.

$$\sum_{i=G,S,B} p_i c_i \leq w_j^m + w_{j'}^f l_{jj'}^f \equiv y_{jj'W} \tag{53}$$

Given market income, households maximise market consumption c. Substituting the budget constraint for c_S, $c_S = \frac{y_j - p_B c_B - p_G c_G}{p_S}$, FOCS are,

$$\frac{\partial c}{\partial c_B} = c^{\frac{1}{\nu}} \left[\phi_B \left(c_B - \underline{B} \right)^{\frac{-1}{\nu}} - \phi_S \left(\hat{c}_S \right)^{\frac{\nu - \sigma}{\sigma \nu}} c_S^{\frac{-1}{\sigma}} \frac{p_B}{p_S} \right] = 0 \tag{54}$$

$$\frac{\partial c}{\partial c_G} = c^{\frac{1}{\nu}} \left[\phi_G \left(c_G \right)^{\frac{-1}{\nu}} - \phi_S \left(\hat{c}_S \right)^{\frac{\nu - \sigma}{\sigma \nu}} c_S^{\frac{-1}{\sigma}} \frac{p_G}{p_S} \right] = 0 \tag{55}$$

$$c_B = \left(\frac{\phi_B}{\phi_S} \frac{p_S}{p_B} \right)^{\nu} \left(\left(\frac{A_w}{c_S} \right)^{\frac{\sigma - 1}{\sigma}} + 1 \right)^{\frac{\sigma - \nu}{\sigma - 1}} c_S + \underline{B} \tag{56}$$

$$c_G = \left(\frac{\phi_G}{\phi_S} \frac{p_S}{p_G} \right)^{\nu} \left(\left(\frac{A_w}{c_S} \right)^{\frac{\sigma - 1}{\sigma}} + 1 \right)^{\frac{\sigma - \nu}{\sigma - 1}} c_S \tag{57}$$

$$c_S + \left[p_B \left(\frac{\phi_B}{\phi_S} \frac{p_S}{p_B} \right)^{\nu} + p_G \left(\frac{\phi_G}{\phi_S} \frac{p_S}{p_G} \right)^{\nu} \right] \left(\left(\frac{A_w}{c_S} \right)^{\frac{\sigma - 1}{\sigma}} + 1 \right)^{\frac{\sigma - \nu}{\sigma - 1}} c_S = y_j - p_B \underline{B}. \tag{58}$$

Equation (58) solves for c_S and Equations (56) and (57) will solve for the remaining consumption allocation.