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The effects of trade on the gender gaps: A model-based quantitative investigation[†]

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Abstract

This paper investigates the role of international trade in explaining the closing gender gaps in the U.S. We build a model with two countries, each of which consists of manufacturing and service sectors as well as female and male labor. A greater female labor intensity in the service sector and an increase in imports of manufacturing varieties generate our key results. The model demonstrates that decreasing trade costs and increasing foreign manufacturing productivity lead to a rise in the service sector at home. This change increases the relative demand for female labor and raises the relative wage for female workers. Our counterfactual analysis quantifies the contribution of trade-related causes in explaining the narrowed gender gaps during the 1968-2008 period.

Keywords: International trade, female labor, gender gaps, service sector
JEL classification: F12, F16, J16, J22, O14

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1. Introduction

A growing body of evidence suggests that international trade substantially affects manufacturing employment (Autor et al., 2013). As men tend to dominate the labor force in manufacturing industries, international trade may influence the relative demand for male labor as well as gender gaps in the labor market. While the remarkable progress of women in the labor market since World War II has been the focus of a vast body of literature, little is known about the role of international trade in driving gender trends.

This paper quantitatively assesses the importance of international trade in narrowing gender gaps in the U.S. Previous studies document that a rise in the service sector is partially responsible for shrinking gender gaps (e.g., Ngai and Petrongolo, 2017; Olivetti and Petrongolo, 2016).[1] Another strand of literature finds that international trade explains the rise in the service sector in developed countries (e.g., Autor et al., 2013, 2019; Caliendo et al. 2019; Feenstra and Sasahara, 2018).[2] While the effect of trade on structural transformation and the effect of structural transformation on gender gaps are studied independently, to the best of our knowledge, none of the existing studies directly link international trade and gender gaps through structural transformation. The goal of this paper is to fill this gap by linking these two channels and by examining the effect of international trade on gender gaps through sectoral resource reallocation.

Figure 1 shows (1) the openness (exports plus imports divided by GDP), (2) gender wage gaps (female divided by male average wages), and (3) gender gaps in labor force participation rates (female divided by male rates), in the U.S. since 1970. It indicates that the openness is increasing, and gender gaps are shrinking over time, suggesting some links between trade and gender gaps.

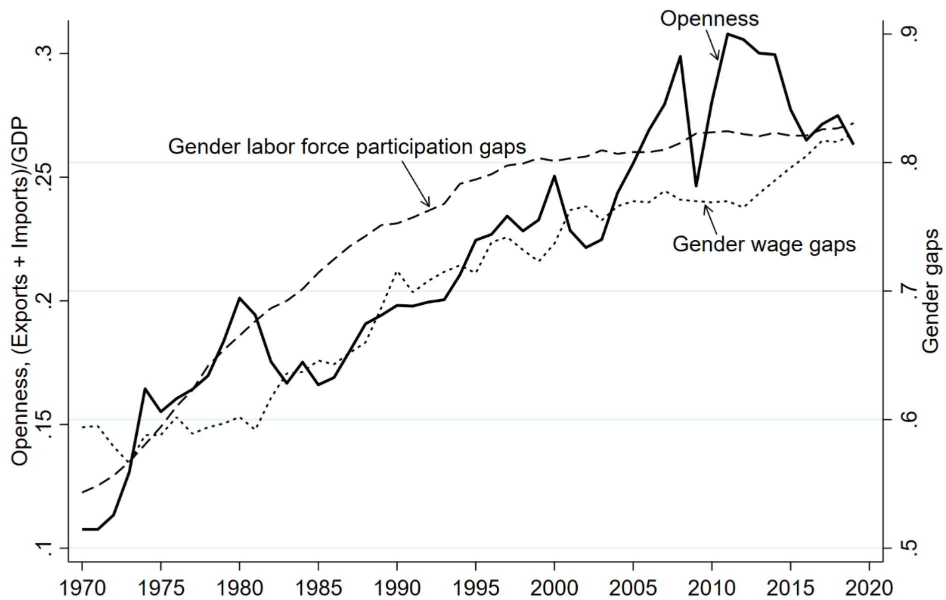
The model is structured as follows. It includes two countries, home and foreign, and two types of labor, female and male. Each country is populated by households, which consist of a female worker and a male worker. There are two sectors in each country, a tradable

[1] Other studies focusing on the link between gender gaps and the service sector include Olivetti and Petrongolo (2014) and Petrongolo and Ronchi (2020). The former finds that cross-country differences in industrial structures explain about one-third of variations in gender gaps. The latter argues that rising shares of the service sector are associated with narrowing gender gaps in the U.S. and the U.K.

[2] Autor et al. (2013, 2019) find that increased import competition reduced manufacturing employment in the U.S., reducing men's earnings because the U.S. manufacturing industry is male-intensive. Caliendo et al. (2019) show that the 'China trade shock' in the U.S. led to a reallocation of workers toward the construction and service sectors. Feenstra and Sasahara (2019) find a similar result using an input-output analysis.

manufacturing sector and a non-tradable service sector. Service varieties are either produced by the household or purchased from the market. Service production is assumed to be more female-intensive than manufacturing production following previous empirical observations (e.g., Autor et al., 2019; Ngai and Petrongolo, 2017). Workers are perfectly mobile across sectors, leading to the same equilibrium wage across sectors. However, wages potentially differ across genders.

Figure 1: Openness and gender gaps in the U.S.



Notes: The data on the gender wage gaps come from the U.S. Department of Labor (https://www.dol.gov/agencies/wb/data/earnings/Gender-ratio-by-race-hispanic). The data on gender gaps in the labor force participation rates (labor force participation rate, female (% of female population ages 15+) (national estimate) and its male counterpart) and the openness (export values plus import values divided by GDP) come from the *World Development Indicators* of the World Bank.

We utilize the model to quantitatively assess the effect of lowering trade costs and raising foreign productivity. In so doing, the model's parameters are calibrated to match its predictions on endogenous variables with data for the two periods, 1968-72 and 2004-08, following Ngai and Petrongolo (2017). Then, we isolate the effect of international trade on gender gaps by keeping the model's parameter values at the initial levels and changing trade-related variables to the 2004-08 levels. To understand the model's mechanisms and the effects of trade on gender gaps, we conduct four counterfactuals considering the effects of (1) a unilateral decrease in foreign-to-home trade costs, (2) a bilateral decrease in trade costs, (3) a unilateral decrease in foreign-to-home trade costs and an increase in foreign productivity, and (4) a bilateral decrease in trade costs and an increase in foreign productivity. According to the results, changes which work to reduce home manufacturing employment (i.e., a decrease in foreign-to-home trade costs and an increase in foreign productivity) decrease gender gaps, while other changes (i.e., a decrease in home-to-foreign trade costs) increase gender gaps. Our central estimate comes from counterfactual (4), which shows that these changes account for about one-fifth of the observed decline in gender gaps in the U.S. during the 1968-2008 period.

Previous trade literature has also studied the effects of trade on gender gaps. However, most of them focus on different channels. For instance, Juhn et al. (2013, 2014) consider trade-induced technology adoption as a source of shrinking gender wage gaps. Similarly, Black and Brainerd (2004) argue that fiercer import competition in the U.S. made it difficult for firms to set discriminatory wages across genders, lowering gender wage gaps. Additionally, Greaney and Tanaka (2021) find that exporting firms have lower gender wage gaps, presumably because multinational firms adopt less discriminatory wage benefits relative to domestic firms. On the other hand, Bøler et al. (2018) find that exporting induced firms to expand gender wage gaps because men are perceived to be more adaptable to the flexible schedules required by exporting firms.[3]

Other studies focus on sectoral resource reallocation as a source of changes in gender gaps. For example, Brussevich (2018) and Besedeš, Lee, and Yang (2021) show that imports from China reduced gender gaps because impacted industries were male-intensive.[4] Sauré and Hosny (2014) find that, when export-oriented sectors are female- and capital-intensive, trade reduces the marginal product of female labor in sectors to which male workers move, increasing gender wage gaps. Nevertheless, our mechanism does not contradict Sauré and Hosny (2014). They consider resource reallocation within tradable sectors while our analysis is based on the overall manufacturing and service sectors.

Apart from the trade literature, previous studies document other mechanisms leading to a decline of gender gaps. For example, Black and Spitz-Oener (2008) describe that technological progress changed the composite of tasks performed by women, from routing tasks to analytical

[3] Based on a similar logic, Vahter and Masso (2019) explain greater gender wage gaps in foreign-owned firms in Ethiopia. Other prior work in this category includes Berik et al. (2004), Kis-Katos et al. (2010), Gaddis and Pieters (2016), Kiyota and Maruyama (2018), and Choi and Greaney (2020).

[4] In Brussevich (2018), different genders have different sectoral mobility costs, which translate into different welfare gains from trade. Besedeš, Lee, and Yang (2021) examine the effect of trade with China on gender gaps using MSA-level data.

and interactive tasks, which led to a decrease in gender gaps in West Germany. Heath and Jayachandran (2016) argue that an increased school enrollment rate for females accounts for lowered gender gaps. While these elements are pertinent, our focus differs from these studies.

The rest of the paper is organized as follows. Section 2 presents a theoretical model. Section 3 calibrates the model's parameters and conducts a qualitative assessment to understand the role of international trade in explaining the decrease in gender gaps. Section 4 offers concluding remarks.

2. Model

2.1 The basic structure

This section describes the model. It includes two monopolistically competitive markets, the tradable manufacturing sector and non-tradable service sector. The economy is populated by a mass $\mathcal{L}$ of households, each of which consists of a female and male worker. Female and male variables are denoted with subscripts *f* and *m*, respectively. Labor is mobile across the two sectors. However, a gender wage gap $w_f \neq w_m$ exists potentially because different labor markets are defined for female and male.

The manufacturing and service sectors produce a number of varieties, which are consumed by each household. We assume that production of service varieties requires more female labor than production of manufacturing varieties. While the manufacturing varieties need to be purchased from the market, the service varieties can be produced at home or purchased from the market. Each female and male worker is endowed with L_f and L_m units of time, respectively. Although $L_f = L_m$, subscripts *f* and *m* clarify that each individual has her/his own endowment.

2.2 Preferences

Each household chooses the consumption quantity of the compound of manufacturing varieties C_g, the compound of service varieties C_z, and the leisure consumption L_l to maximize the following utility function:

$$U\left(C_g, C_s, C_h, L_l\right) = \ln\left[\alpha_g C_g^{\frac{\varepsilon-1}{\varepsilon}} + \alpha_z C_z^{\frac{\varepsilon-1}{\varepsilon}}\right]^{\frac{\varepsilon}{\varepsilon-1}} + \varphi \ln(L_l), \qquad (1)$$

where $\varepsilon > 1$ is the elasticity of substitution between the manufacturing and service compounds. α_g and α_z, where these satisfy $\alpha_g + \alpha_z = 1$, and φ are parameters. The service consumption C_z is modelled as a composite of the service good produced in the market C_s and the one produced at home C_h as follows:

$$C_z = \left[\beta_s C_s^{\frac{\mu-1}{\mu}} + \beta_h C_h^{\frac{\mu-1}{\mu}}\right]^{\frac{\mu}{\mu-1}} \text{ with } \beta_s + \beta_h = 1,$$

where β_s and β_h are parameters. μ indicates the elasticity of substitution between the market services and the at home services. Because the level of substitution between C_s and C_h is greater than the level of substitution between C_g and C_z, $\mu > \varepsilon$.

The household service production C_h can be produced by either a female worker or a male worker. Therefore, C_h is expressed as the following CES production function:

$$C_h = \left[\xi_{hf} L_{hf}^{\frac{\eta_h-1}{\eta_h}} + \xi_{hm} L_{hm}^{\frac{\eta_h-1}{\eta_h}}\right]^{\frac{\eta_h}{\eta_h-1}} \text{ with } \xi_{hf} + \xi_{hm} = 1,$$

where L_{hf} and L_{hm} are time spent for service production at home for the female and male worker, respectively. ξ_{hf} and ξ_{hm} are parameters. $\eta_h > 1$ denotes the elasticity of substitution between the two inputs. The composite leisure consumption L_l is also expressed as a CES aggregator:

$$L_l = \left[\xi_{lf} L_{lf}^{\frac{\eta_l-1}{\eta_l}} + \xi_{lm} L_{lm}^{\frac{\eta_l-1}{\eta_l}}\right]^{\frac{\eta_l}{\eta_l-1}} \text{ with } \xi_{lf} + \xi_{lm} = 1, \qquad (2)$$

where L_{hf} and L_{hm} are time spent for leisure for the female and male worker, respectively. ξ_{fl} and ξ_{ml} are parameters. $\eta_l > 1$ denotes the elasticity of substitution.

Each household maximizes equation (1) subject to the budget constraint: $P_g C_g + P_s C_s = w_f\left(L_f - L_{hf} - L_{lf}\right) + w_m(L_m - L_{hm} - L_{lm})$. P_g and P_s are the CES price indices of the manufacturing good and the service good. The right-hand side of the budget constraint expresses earnings of the household: the wage rate w_k multiplied by the amount of time devoted for market production, $L_k - L_{hk} - L_{lk}$, for $k = f, m$. Each household solves the maximization problem by taking the prices, P_g, P_s, w_f, w_m, as given.

2.3 Utility maximization

Solving the utility maximization problem leads to the following solution to the amount of time spent for housework (e.g., service production at home):

$$L_{hk} = \frac{\xi_{hk}^{\eta_h} w_k^{-\eta_h}}{W_h^{1-\eta_h}} \frac{\beta_h^{\mu} W_h^{1-\mu}}{\Phi^{1-\mu}} \frac{\alpha_z^{\varepsilon} \Phi^{1-\varepsilon}}{\Theta^{1-\varepsilon}} \quad \text{for } k = f, m, \tag{3}$$

where

$$W_h = \left[\xi_{hf}^{\eta_h} w_f^{1-\eta_h} + \xi_{hm}^{\eta_h} w_m^{1-\eta_h}\right]^{1/(1-\eta_h)},$$

$$\Phi = \left[\beta_s^{\mu} P_s^{1-\mu} + \beta_h^{\mu} W_h^{1-\mu}\right]^{1/(1-\mu)},$$

$$\Theta = \left[\alpha_g^{\varepsilon} P_g^{1-\varepsilon} + \alpha_z^{\varepsilon} \Phi^{1-\varepsilon}\right]^{1/(1-\varepsilon)},$$

are the CES wage index, the CES service price index, and the overall CES price index, respectively. The solution to the amount of time spent for leisure is

$$L_{lk} = \varphi \frac{\xi_{lk}^{\eta_l} w_k^{-\eta_l}}{W_l^{1-\eta_l}} \quad \text{for } k = f, m, \tag{4}$$

where $W_l = \left[\xi_{lf}^{\eta_l} w_f^{1-\eta_l} + \xi_{lm}^{\eta_l} w_m^{1-\eta_l}\right]^{1/(1-\eta_l)}$. Plugging (3) and (4) into the CES leisure aggregator (2) leads to $L_l = \varphi W_l^{-1}$. Using (3) and (4), the female and male labor supplies are found as follows:

$$\begin{aligned} L_k^{Supply} &= \mathcal{L}(L_k - L_{hk} - L_{lk}) \\ &= \mathcal{L}\left(L_k - \frac{\xi_{hk}^{\eta_h} w_k^{-\eta_h}}{W_h^{1-\eta_h}} \frac{\beta_h^{\mu} W_h^{1-\mu}}{\Phi^{1-\mu}} \frac{\alpha_z^{\varepsilon} \Phi^{1-\varepsilon}}{\Theta^{1-\varepsilon}} - \varphi \frac{\xi_{lk}^{\eta_l} w_k^{-\eta_l}}{W_l^{1-\eta_l}}\right) \text{ for } k = f, m. \end{aligned} \tag{5}$$

Each household's utility maximizing consumptions of the manufacturing good and the service good are

$$C_g = \frac{\alpha_g^{\varepsilon} P_g^{-\varepsilon}}{\Theta^{1-\varepsilon}}, C_s = \frac{\beta_s^{\mu} P_s^{1-\mu}}{\Phi^{1-\mu}} \frac{\alpha_z^{\varepsilon} \Phi^{-\varepsilon}}{\Theta^{1-\varepsilon}}, \tag{6}$$

respectively. Within each of the manufacturing and service sectors, a large number of varieties exist. Therefore, each household chooses the consumption quantity of each variety by solving the following maximization problem:

$$\max \left[\int q_i(\omega)^{\frac{\sigma_i - 1}{\sigma_i}} d\omega\right]^{\frac{\sigma_i}{\sigma_i - 1}} \text{ s.t.} \int p_i(\omega) q_i(\omega)\, d\omega = C_i P_i \quad \text{for } i = g, s$$

where $q_i(\omega)$ indicates the consumption quantity of variety ω of the good $i = g, s$; $\sigma_i > 1$ denotes the elasticity of substitution between varieties. C_i comes from equation (6). Given that there is a mass $\mathcal{L}$ of households, solving the problem yields the following demand for each variety:

$$Q_g(\omega) = q_g(\omega)\mathcal{L} = \frac{p_g(\omega)^{-\sigma_g}}{P_g^{1-\sigma_g}} \frac{\alpha_g^\varepsilon P_g^{-\varepsilon}}{\Theta^{1-\varepsilon}} \mathcal{L},$$

$$Q_s(\omega) = q_s(\omega)\mathcal{L} = \frac{p_s(\omega)^{-\sigma_g}}{P_s^{1-\sigma_s}} \frac{\beta_s^\mu P_s^{1-\mu}}{\Phi^{1-\mu}} \frac{\alpha_z^\varepsilon \Phi^{-\varepsilon}}{\Theta^{1-\varepsilon}} \mathcal{L}.$$

2.4 Open economy

The model includes two markets, the domestic market at home, *D*, and the foreign market, *F*. In the domestic market, each domestic firm faces the following demands:

$$Q_g^{DD}(\omega) = \frac{p_g^{DD}(\omega)^{-\sigma_g}}{(P_g^D)^{1-\sigma_g}} \frac{\alpha_g^\varepsilon (P_g^D)^{-\varepsilon}}{(\Theta^D)^{1-\varepsilon}} \mathcal{L}^D \text{ and } Q_s^{DD}(\omega) = \frac{p_s^{DD}(\omega)^{-\sigma_s}}{(P_s^D)^{1-\sigma_s}} \frac{\beta_s^\mu (P_s^D)^{1-\mu}}{(\Phi^D)^{1-\mu}} \frac{\alpha_z^\varepsilon (\Phi^D)^{-\varepsilon}}{(\Theta^D)^{1-\varepsilon}} \mathcal{L}^D, \quad (7)$$

where $Q_g^{DD}(\omega)$ is the demand in the domestic manufacturing market and $Q_s^{DD}(\omega)$ is the demand in the domestic service market. In addition, firms serve the foreign market by including variable iceberg trade costs, which will be introduced in the next section. In the foreign market, each firm faces the following demands:

$$Q_g^{DF}(\omega) = \frac{p_g^{DF}(\omega)^{-\sigma_g}}{(P_g^F)^{1-\sigma_g}} \frac{\alpha_g^\varepsilon (P_g^F)^{-\varepsilon}}{(\Theta^F)^{1-\varepsilon}} \mathcal{L}^F \text{ and } Q_s^{DF}(\omega) = \frac{p_s^{DF}(\omega)^{-\sigma_s}}{(P_s^F)^{1-\sigma_s}} \frac{\beta_s^\mu (P_s^F)^{1-\mu}}{(\Phi^F)^{1-\mu}} \frac{\alpha_z^\varepsilon (\Phi^F)^{-\varepsilon}}{(\Theta^F)^{1-\varepsilon}} \mathcal{L}^F. \quad (8)$$

where $Q_g^{DF}(\omega)$ and $Q_s^{DF}(\omega)$ are for the foreign manufacturing and foreign service markets, respectively. Demands faced by foreign firms, $Q_i^{FF}(\omega)$ and $Q_i^{FD}(\omega)$, where $i = g, s$, are defined as mirror images.

2.5 Firms' production technologies

This section describes market structures and firms' production technologies. The manufacturing sector and the service sector are monopolistically competitive. Firms are free to enter and exit each market. As a result, each firm earns a zero profit in the equilibrium. Because all firms in the same market are homogeneous and behave symmetrically, variety index ω is dropped hereafter. Because home and foreign markets are symmetric, we only discuss firms at home.

Each firm incurs three types of costs: (1) variable costs for domestic production, (2) variable costs to export a variety, and (3) fixed production costs.[5] These costs are incurred using labor. Specifically, each domestic firm in sector $i = g, s$ solves the following cost minimization problems:

$$\min_{L_{fi},L_{mi}} \; w_f^D L_{fi} + w_m^D L_{mi} \quad \text{s.t.} \quad A_i^D \left(\frac{L_{fi}}{\gamma_i}\right)^{\gamma_i} \left(\frac{L_{mi}}{1-\gamma_i}\right)^{1-\gamma_i} \geq Q_i^{DD}, \tag{9}$$

$$\min_{L_{fi},L_{mi}} \; w_f^D L_{fi} + w_m^D L_{mi} \quad \text{s.t.} \quad \frac{A_i^D}{\tau_i^{DF}} \left(\frac{L_{fi}}{\gamma_i}\right)^{\gamma_i} \left(\frac{L_{mi}}{1-\gamma_i}\right)^{1-\gamma_i} \geq Q_i^{DF}, \tag{10}$$

$$\min_{L_{fi},L_{mi}} \; w_f^D L_{fi} + w_m^D L_{mi} \quad \text{s.t.} \quad \left(\frac{L_{fi}}{\gamma_i}\right)^{\gamma_i} \left(\frac{L_{mi}}{1-\gamma_i}\right)^{1-\gamma_i} \geq \theta_i, \tag{11}$$

where L_{fi} and L_{mi} denote female and male labor employed by a firm in sector $i = g, s$; A_i^D indicates the productivity of sector *i* at home; $\gamma_i \in (0,1)$ indicates the female labor intensity; τ_i^{DF} indicates iceberg trade costs that each firm incurs to ship a variety from home to the foreign country[6]; Q_i^{DD} and Q_i^{DF} come from equations (7) and (8), respectively; and θ_i denotes fixed costs. Equations (9) and (10) express the cost minimization problem associated with variable costs to serve the domestic and foreign market, respectively.[7] Lastly, equation (11) expresses the cost minimization problem associated with incurring fixed costs.

Solving the cost minimization problems leads to the following minimized costs required to produce a variety for the domestic market:

$$w_f^D L_{fi}^{DD} + w_m^D L_{mi}^{DD} = \frac{1}{A_i^D} (w_f^D)^{\gamma_i} (w_m^D)^{1-\gamma_i} Q_i^{DD} \quad \text{for} \quad i = g, s, \tag{12}$$

where L_{fi}^{DD} and L_{mi}^{DD} are female and male labor, respectively. The minimized costs required to produce a variety for the export market are

$$w_f^D L_{fi}^{DF} + w_m^D L_{mi}^{DF} = \frac{\tau_i^{DF}}{A_i^D} (w_f^D)^{\gamma_i} (w_m^D)^{1-\gamma_i} Q_i^{DF} \quad \text{for} \quad i = g, s, \tag{13}$$

[5] We assume that there is no fixed cost for exporting.
[6] An inverse of the iceberg trade costs is multiplied by the production function, meaning that a certain share of production will be lost when a variety is shipped from one country to another.
[7] Firms are homogeneous in their productivities. Therefore, all firms export in the open economy.

where L_{fi}^{DF} and L_{mi}^{DF} are female and male labor, respectively. The minimized fixed costs are

$$w_f^D L_{fi}^{D\theta} + w_m^D L_{mi}^{D\theta} = (w_f^D)^{\gamma_i}(w_m^D)^{1-\gamma_i}\theta_i \quad \text{for} \quad i = g, s, \tag{14}$$

where $L_{fi}^{D\theta}$ and $L_{mi}^{D\theta}$ are female and male labor, respectively.

Using (12)-(14), the profit earned by each domestic firm in sector *i* is obtained as follows:

$$\pi_i^D = \underbrace{\left(p_i^{DD} - \frac{\left(w_f^D\right)^{\gamma_i}(w_m^D)^{1-\gamma_i}}{A_i^D}\right)X_i^{DD}}_{\pi_i^{DD}} + \underbrace{\left(p_i^{DF} - \frac{\tau_i^{DF}\left(w_f^D\right)^{\gamma_i}(w_m^D)^{1-\gamma_i}}{A_i^D}\right)X_i^{DF}}_{\pi_i^{DF}} - \underbrace{\left(w_f^D\right)^{\gamma_i}(w_m^D)^{1-\gamma_i}\theta_i}_{\text{Fixed costs}}, \tag{15}$$

where π_i^{DD} and π_i^{DF} are profits (not taking fixed costs into account) from the domestic and foreign market, respectively. Each domestic firm chooses its optimal price in each market by solving the profit maximization problems: $\max_{p_i^{DD}} \pi_i^{DD}$ and $\max_{p_i^{DF}} \pi_i^{DF}$. The profit-maximizing prices are:

$$p_i^{DD} = \frac{\sigma_i}{\sigma_i - 1}\frac{\left(w_f^D\right)^{\gamma_i}(w_m^D)^{1-\gamma_i}}{A_i^D} \quad \text{and} \quad p_i^{DF} = \frac{\sigma_i}{\sigma_i - 1}\frac{\tau_i^{DF}\left(w_f^D\right)^{\gamma_i}(w_m^D)^{1-\gamma_i}}{A_i^D}. \tag{16}$$

The CES price index is

$$P_i^D = \frac{\sigma_i}{\sigma_i - 1}\left[N_i^D\left(\frac{\left(w_f^D\right)^{\gamma_i}(w_m^D)^{1-\gamma_i}}{A_i^D}\right)^{1-\sigma_i} + N_i^F\left(\frac{\tau_i^{FD}\left(w_f^F\right)^{\gamma_i}(w_m^F)^{1-\gamma_i}}{A_i^F}\right)^{1-\sigma_i}\right]^{1/(1-\sigma_i)},$$

where N_i^D and N_i^F are the mass of firms at home and in the foreign country, respectively. Plugging (16) into (15) yields the following profit functions:

$$\pi_g^D = \kappa_{1g}\left(\frac{\left(w_f^D\right)^{\gamma_g}(w_m^D)^{1-\gamma_g}}{A_g^D}\right)^{1-\sigma_g}\left(\frac{\left(P_g^D\right)^{\sigma_g-\varepsilon-1}\mathcal{L}^H}{(\Theta^D)^{1-\varepsilon}} + \frac{\left(P_g^F\right)^{\sigma_g-\varepsilon-1}\mathcal{L}^F}{\left(\tau_g^{DF}\right)^{\sigma_g-1}(\Theta^F)^{1-\varepsilon}}\right) \tag{17}$$

$$- \left(w_f^D\right)^{\gamma_g}(w_m^D)^{1-\gamma_g}\theta_g,$$

$$\pi_s^D = \kappa_{1s}\left(\frac{\left(w_f^D\right)^{\gamma_s}(w_m^D)^{1-\gamma_s}}{A_s^D}\right)^{1-\sigma_s}\left(\frac{(P_s^D)^{\sigma_s-\mu-1}(\Theta^D)^{\mu-\varepsilon}\mathcal{L}^D}{(\Theta^D)^{1-\varepsilon}} + \frac{(P_s^F)^{\sigma_s-\varepsilon-1}(\Theta^F)^{\mu-\varepsilon}\mathcal{L}^F}{(\tau_s^{DF})^{\sigma_s-1}(\Theta^F)^{1-\varepsilon}}\right) \tag{18}$$

$$- \left(w_f^D\right)^{\gamma_s}(w_m^D)^{1-\gamma_s}\theta_s,$$

where $\kappa_{1g} = \frac{(\sigma_g-1)^{\sigma_g-1}}{(\sigma_g)^{\sigma_g}}\alpha_g^\varepsilon$ and $\kappa_{1s} = \frac{(\sigma_s-1)^{\sigma_s-1}}{(\sigma_s)^{\sigma_s}}\alpha_z^\varepsilon\beta_s^\mu$.

2.6 Labor markets

This section derives the labor market clearing conditions, starting with labor demands. Solving the cost minimization problem (9) yields the following labor demands to produce varieties sold in the domestic market:

$$L_{fi}^{DD} = \frac{\gamma_i}{A_i^D}\left(\frac{w_m^D}{w_f^D}\right)^{1-\gamma_i} Q_i^{DD} \quad \text{and} \quad L_{mi}^{HH} = \frac{1-\gamma_i}{A_i^D}\left(\frac{w_f^D}{w_m^D}\right)^{\gamma_i} Q_i^{DD} \quad \text{for} \quad i = g, s. \qquad (19)$$

By solving the cost minimization problem (10), the labor demands to produce varieties sold in the foreign market are obtained as follows:

$$L_{fi}^{DF} = \tau_i^{DF}\frac{\gamma_i}{A_i^D}\left(\frac{w_m^D}{w_f^D}\right)^{1-\gamma_i} Q_i^{DF} \quad \text{and} \quad L_{mi}^{DF} = \tau_i^{DF}\frac{1-\gamma_i}{A_i^D}\left(\frac{w_f^D}{w_m^D}\right)^{\gamma_i} Q_i^{DF} \quad \text{for} \quad i = g, s. \qquad (20)$$

Lastly, solving the cost minimization problem (11) yields the labor demands required to incur fixed costs as follows:

$$L_{fi}^{D\theta} = \gamma_i\left(\frac{w_m^D}{w_f^D}\right)^{1-\gamma_i} \theta_i \quad \text{and} \quad L_{mi}^{D\theta} = (1-\gamma_i)\left(\frac{w_f^D}{w_m^D}\right)^{\gamma_i} \theta_i \quad \text{for} \quad i = g, s. \qquad (21)$$

Using equations (19)-(21), the demand for female labor at home is

$$L_f^{D,Demand} = \sum_{i\in\{g,s\}}\left(L_{fi}^{DD} + L_{fi}^{DF} + L_{fi}^{D\theta}\right)$$

$$= \gamma_g N_g^D\left(\frac{w_m^D}{w_f^D}\right)^{1-\gamma_g}\left\{\kappa_{2g}\frac{\left[\left(w_f^D\right)^{\gamma_i}(w_m^D)^{1-\gamma_i}\right]^{-\sigma_g}}{\left(A_g^D\right)^{\sigma_g-1}}\left[\begin{array}{c}\dfrac{\left(P_g^D\right)^{\sigma_g-\varepsilon-1}\mathcal{L}^H}{(\Theta^D)^{1-\varepsilon}} \\ +\dfrac{\left(P_g^F\right)^{\sigma_g-\varepsilon-1}\mathcal{L}^F}{\left(\tau_g^{DF}\right)^{\sigma_g-1}(\Theta^F)^{1-\varepsilon}}\end{array}\right] + \theta_g\right\} \qquad (22)$$

$$+ \gamma_s N_s^D\left(\frac{w_m^D}{w_f^D}\right)^{1-\gamma_s}\left\{\kappa_{2s}\frac{\left[\left(w_f^D\right)^{\gamma_i}(w_m^D)^{1-\gamma_i}\right]^{-\sigma_s}}{(A_s^D)^{\sigma_s-1}}\left[\begin{array}{c}\dfrac{(P_s^D)^{\sigma_s-\mu-1}(\Theta^D)^{\mu-\varepsilon}\mathcal{L}^D}{(\Theta^D)^{1-\varepsilon}} \\ +\dfrac{(P_s^F)^{\sigma_s-\varepsilon-1}(\Theta^F)^{\mu-\varepsilon}\mathcal{L}^F}{(\tau_s^{DF})^{\sigma_s-1}(\Theta^F)^{1-\varepsilon}}\end{array}\right] + \theta_s\right\},$$

where $\kappa_{2g} = \left(\frac{\sigma_g - 1}{\sigma_g}\right)^{\sigma_g} \alpha_g^{\varepsilon}$ and $\kappa_{1s} = \left(\frac{\sigma_s - 1}{\sigma_s}\right)^{\sigma_s} \alpha_z^{\varepsilon} \beta_s^{\mu}$. Furthermore, the demand for male labor at home is

$$L_m^{D,Demand} = \sum_{i \in \{g,s\}} \left(L_{mi}^{DD} + L_{mi}^{DF} + L_{mi}^{D\theta}\right)$$

$$= (1-\gamma_g) N_g^D \left(\frac{w_f^D}{w_m^D}\right)^{\gamma_g} \left\{ \kappa_{2g} \frac{\left[\left(w_f^D\right)^{\gamma_i} (w_m^D)^{1-\gamma_i}\right]^{-\sigma_g}}{\left(A_g^D\right)^{\sigma_g - 1}} \left[\begin{array}{c} \frac{\left(P_g^D\right)^{\sigma_g - \varepsilon - 1} \mathcal{L}^D}{(\Theta^D)^{1-\varepsilon}} \\ + \frac{\left(P_g^F\right)^{\sigma_g - \varepsilon - 1} \mathcal{L}^F}{\left(\tau_g^{DF}\right)^{\sigma_g - 1} (\Theta^F)^{1-\varepsilon}} \end{array} \right] + \theta_g \right\} \quad (23)$$

$$+(1-\gamma_s) N_s^D \left(\frac{w_f^D}{w_m^D}\right)^{\gamma_s} \left\{ \kappa_{2s} \frac{\left[\left(w_f^D\right)^{\gamma_i} (w_m^D)^{1-\gamma_i}\right]^{-\sigma_s}}{(A_s^D)^{\sigma_s - 1}} \left[\begin{array}{c} \frac{(P_s^D)^{\sigma_s - \mu - 1} (\Theta^D)^{\mu - \varepsilon} \mathcal{L}^H}{(\Theta^D)^{1-\varepsilon}} \\ + \frac{(P_s^F)^{\sigma_s - \varepsilon - 1} (\Theta^F)^{\mu - \varepsilon} \mathcal{L}^F}{(\tau_s^{DF})^{\sigma_s - 1} (\Theta^F)^{1-\varepsilon}} \end{array} \right] + \theta_s \right\}.$$

By equating these labor demands with labor supplies in equation (5), we obtain the labor market clearing conditions: $L_k^{D,Supply} = L_k^{D,Demand}$ for $i = g, s$.

2.7 Equilibrium

We define the equilibrium of the model in this section. The model includes eight endogenous variables: $\{w_f^D, w_m^D, w_f^F, w_m^F, N_g^D, N_s^D, N_g^F, N_s^F\}$. These are obtained using the following eight equilibrium conditions: the zero profit conditions in sector $i = g, s$ at home and in the foreign country (equations 17 and 18 and their foreign counterparts, totaling four equations), the female labor market clearing conditions (equation 22 and its foreign counterpart), and the male labor market clearing conditions (equation 23 and its foreign counterpart). The model is solved numerically.

3. Calibration

3.1 The model's parameters

To solve the model numerically, we assume parameter values as summarized in Table 1. The parameter values of α, θ_g, θ_s, L_f, L_m, and $\mathcal{L}$ are chosen arbitrarily. We use the same parameter values as Ngai and Petrongolo (2017) regarding the female intensities, ξ_{hf} and ξ_{lf}, and the elasticities of substitution between female and male, η_h and η_l. The service sector is assumed to be a non-tradable sector: $\tau_s = +\infty$. These assumptions are symmetrically made across the two countries.

Asymmetric parameter assumptions across the two countries are summarized in Panel B of Table 1. The home manufacturing and service productivity levels are set to unity and 0.82, respectively.[8] The two countries' productivity levels are the same initially. Then, the foreign country's productivity levels grow by 10% from the first period to the second period.[9]

Table 1: Given parameter values

Panel A: Symmetric across the two countries

Parameter	*Interpretation*
$\alpha_z = 0.50$	Manufacturing good share in the first-tier utility function
$\xi_{hf} = 0.50$	Female intensity in household service production
$\xi_{lf} = 0.29$	Female intensity in the leisure utility
$\eta_h = 2.27$	Elasticity of substitution between female and male in household service production
$\eta_l = 0.19$	Elasticity of substitution between female and male in the leisure utility
$\theta_g = \theta_s = 1$	Fixed costs of production
$L_f = L_m = 1$	Per worker hour endowment
$\mathcal{L} = 120$	Mass of households
$\tau_s = +\infty$	Trade costs in services

Note: Subscripts *H* and *F* are omitted because these variables are symmetric across countries.

Panel B: Asymmetric across the two countries

Interpretation	1968-72	2004-08
Home manufacturing productivity A_g^D	1	1
Home service productivity A_s^D	0.82	0.82
Foreign manufacturing productivity A_g^F	1	1×1.1
Foreign service productivity A_s^F	0.82	0.82×1.1

[8] The productivity gap is based on U.S. labor productivities calculated based on the data from EU KLEMS (http://www.euklems.net/). The earliest data come from 2000, when the average labor productivity of services (information and communication; finance and insurance activities; and professional, scientific, technical, administrative and support service activities) is 82% of the average labor productivity of total manufacturing.

[9] The purpose of this study is to investigate the effect of an increase in international trade, especially imports, on the gender wage gap. In the model, imports from the foreign country increase for two reasons: a decrease in trade costs and an increase in foreign productivity. We do not attempt to isolate the effects of these two factors. Therefore, the growth rate of foreign productivity is assumed to be arbitrary.

Given these parameter assumptions, the remaining parameters to find are $\{\beta, \varepsilon, \mu, \gamma_g, \gamma_s, \phi, \sigma_g, \sigma_s, \tau_g^{DF}, \tau_g^{FD}\}$. These parameters are symmetric across the two countries except for trade costs in the manufacturing sector, τ_g^{DF} and τ_g^{FD}. All ten parameters are calibrated to match the model with data. As summarized in Table 2, the target moments are: (1) the service employment share (both genders), (2) the hour share for manufacturing work (both genders), (3) the hour share for service work (both genders), (4) the service expenditure share, (5) the imports-to-domestic production share, (6) the exports-to-domestic production share, and (7) the gender wage ratio, $\frac{female\ wage}{male\ wage}$. Following Ngai and Petrongolo (2017), these moments are found in the two states, 1968-72 and 2004-08.[10]

Table 2: Target moments

	1968-72		2004-08	
Variable	Data	Model	Data	Model
1. Service employment share, female	0.76	0.74	0.87	0.87
2. Service employment share, male	0.51	0.52	0.63	0.63
3. Hour share for manufacturing work, female	0.05	0.07	0.04	0.05
4. Hour share for manufacturing work, male	0.23	0.17	0.15	0.13
5. Hour share for service work, female	0.17	0.21	0.25	0.28
6. Hour share for service work, male	0.24	0.18	0.25	0.23
7. Service expenditure share	0.62	0.46	0.76	0.75
8. Imports/domestic production ratio	0.06	0.06	0.15	0.15
9. Exports/domestic production ratio	0.05	0.05	0.10	0.10
10. Female wage/male wage	0.63	0.63	0.78	0.78

Note: The data on variables 1-6 and 10 are obtained from Ngai and Petrongolo (2017). The data on variable 7 come from the Bureau of Economic Analysis of the U.S. Variables 8 and 9 are from the WDI.

The data on moments (1)-(3) and (7) come from Ngai and Petrongolo (2017). The data on moment (4) are obtained from the Bureau of Economic Analysis of the U.S.[11] The data on imports and exports come from the World Development Indicators of the World Bank. The data and the model's predictions on these variables in 1968-72 and 2004-08 are shown in Table 2. These parameters are calibrated to minimize the distance between the model and the data. All variables matched well.

Table 3 shows the calibrated parameters. The parameter values fall in a reasonable range. For example, low values of the elasticity of substitution between the manufacturing good and the service, ε, and high values of the elasticity of substitution between the market service and the

[10] We closely follow the analysis by Ngai and Petrongolo (2017) and focus on the two steady-states.
[11] The Historical Industry Accounts Data at https://www.bea.gov/industry/io-histannual.

home service, μ, are consistent with Ngai and Petrongolo (2017).[12] The lower female intensities in the manufacturing sector, γ_g, and the higher female intensities in the service sector, γ_s, are consistent with our assumption.

Table 3: Calibrated parameters

Parameter	1968-72	2004-08
Market service share in the utility C_z, β_s	0.49	0.25
Elasticity of substitution between the manufacturing good and the service, ε	0.21	0.32
Elasticity of substitution between the market service and the home service, μ	1.27	1.85
Female intensity in manufacturing production, γ_g	0.20	0.24
Female intensity in service production, γ_s	0.42	0.53
Preferences for leisure, ϕ	1.81	3.01
Elasticity of substitution between manufacturing varieties, σ_g	2.46	2.14
Elasticity of substitution between service varieties, σ_s	2.97	2.22
Trade costs to export from home to foreign, τ_g^{DF}	3.78	1.49
Trade costs to export from foreign to home, τ_g^{FD}	3.64	1.21

The elasticities of substitution between manufacturing varieties and service varieties are 2–3. Iceberg trade costs for manufacturing exports are 3.78 for home-to-foreign and 3.64 for foreign-to-home for the period 1968-72. These costs decline to 1.49 and 1.21 for the period 2004-08, respectively. These trade costs may seem high. This is because monetary and non-monetary transaction costs and non-tariff barriers are included. The other parameters are also reasonable.[13,14]

3.2 Counterfactuals

Columns (1) and (2) of Table 4 show the solutions to ten endogenous variables – (1) the female service employment share, (2) the male service employment share, (3) the female hour share for manufacturing work, (4) the male hour share for manufacturing work, (5) the female

[12] In Ngai and Petrongolo (2017), $\varepsilon = 0.002$ and $\mu = 2.0$ following Herrendorf et al. (2013) and Aguiar et al. (2012), respectively.

[13] The service share in the utility function, β, is 0.49 for the 1968-72 period while it is 0.25 for the 2004-08 period. The smaller value in the latter period may be counterintuitive because the expenditure share on the service good increased from the first period to the second period, as shown in Table 2. This is because service employment is greater in the latter period, which leads to a greater number of service firms. As a result, the CES price index for the service sector is lower in the latter period. This change works to increase the expenditure share for the service good, presumably more than enough to match the actual increase in the service expenditure share observed in the data. Therefore, to partially offset the increase in the expenditure share for the service good, the market share in the utility function, β, needs to decline.

[14] The parameter capturing the preferences for leisure ϕ is 1.81 for the former period and 3.01 for the latter period. This change is presumably because increased international trade works to increase labor supply more than the data suggest, offsetting the greater increase in the labor supply by raising the utility from leisure.

hour share for service work, (6) the male hour share for service work, (7) the service expenditure share, (8) the imports-to-domestic production ratio, (9) the exports-to-domestic production ratio, and (10) the gender wage ratio – for both the 1968-72 period and the 2004-08 period.

Using the calibrated parameters reported in Table 3, we conduct a counterfactual analysis to isolate the effect of international trade caused by decreasing iceberg trade costs and raising foreign productivity. We first find the solutions to the ten endogenous variables listed in Table 4 by fixing the parameter values $\Theta = \{\beta, \varepsilon, \mu, \gamma_g, \gamma_s, \phi, \sigma_g, \sigma_s, \tau_g^{DF}, \tau_g^{FD}\}$ at the 1968-72 level and changing a subset of our key parameters, $\{\tau_g^{FD}, \tau_g^{DF}, A_g^F, A_s^F\}$, to the 2004-08 level.

Table 4: Counterfactuals

	Model		Counterfactuals			
	68-72 (1)	04-08 (2)	V_1 (3)	V_2 (4)	V_3 (5)	V_4 (6)
Θ		Y				
τ_g^{FD}		Y	Y	Y	Y	Y
τ_g^{DF}		Y		Y		Y
A_g^F and A_s^F		Y			Y	Y
Service employment share, female	0.77	0.87	0.92	0.81	0.94	0.83
Service employment share, male	0.54	0.63	0.80	0.60	0.84	0.63
Hour share for manu. work, female	0.07	0.04	0.02	0.05	0.02	0.05
Hour share for manu. work, male	0.16	0.10	0.06	0.14	0.05	0.13
Hour share for service work, female	**0.217**	**0.296**	**0.255**	**0.231**	**0.260**	**0.237**
Hour share for service work, male	0.19	0.20	0.24	0.21	0.25	0.21
Service expenditure share	0.55	0.76	0.56	0.54	0.56	0.54
Imports/domestic production	0.06	0.15	0.43	0.25	0.48	0.30
Exports/domestic production	0.05	0.10	0.02	0.13	0.02	0.12
Female wage/male wage	**0.630**	**0.779**	**0.700**	**0.649**	**0.710**	**0.659**
$\frac{\text{Counterfactual wage} - 0.63}{0.78 - 0.63}$			**0.46**	**0.13**	**0.53**	**0.19**
$\frac{\text{Counterfactual female service hour} - 0.63}{0.78 - 0.63}$			**0.47**	**0.18**	**0.54**	**0.24**

Notes: $\Theta = \{\beta, \varepsilon, \mu, \gamma_g, \gamma_s, \phi, \sigma_g, \sigma_s\}$.

Columns (3)-(6) report four different patterns of counterfactuals. First, column (3) presents the result when foreign-to-home trade costs are changed to the 2004-08 level and other parameters are held constant at the 1968-72 level. We call it $V_1 = V(\Theta_{72}, \tau_{g08}^{FD}, \tau_{g72}^{DF}, A_{g72}^F, A_{s72}^F)$. Counterfactual V_1 leads to a gender wage ratio of 0.674, meaning that the decreased trade costs to export from foreign to home explain (0.70 – 0.63)/(0.78 – 0.63)×100 = 46% of the observed decline in the gender wage ratio. A similar calculation implies that V_1 explains (0.255 – 0.21)/(0.28 – 0.21) = 47% of the observed increase in female service hours. A decrease in τ_g^{FD}

raises the toughness of the manufacturing market competition, facilitating sectoral labor reallocation toward services. This change works to reduce the gender gaps.

In counterfactual V_2, trade costs τ_g^{FD} and τ_g^{DF} are changed to the 2004-08 levels bilaterally: $V_2 = V(\Theta_{72}, \tau_{g08}^{FD}, \tau_{g08}^{DF}, A_{g72}^{F}, A_{s72}^{F})$, resulting in a gender wage ratio of 0.649. The increase in the ratio and the increase in female service hours are less than in V_1. This is because a decrease in τ_g^{DF} increases manufacturing exports from home to foreign, working to retain the manufacturing employment at a higher level. The implied contributions of trade are (0.649 – 0.63)/(0.78 – 0.63)×100 = 13% for the gender wage gap, and (0.231 – 0.21)/(0.28 – 0.21) = 18% for female service employment.

Counterfactual V_3 is when foreign-to-home trade costs τ_g^{FD} and foreign productivity levels changed to the 2004-08 level: $V_3 = V(\Theta_{72}, \tau_{g08}^{FD}, \tau_{g72}^{DF}, A_{g08}^{F}, A_{g08}^{D})$. A growth of foreign productivity increases foreign exports to home, raising the toughness of the manufacturing market. This in turn induces resource reallocation toward services, reducing the gender wage gap. The computed gender wage ratio based on V_3 is 0.695, meaning that the changes in these three parameters account for (0.649 – 0.63)/(0.78 – 0.63)×100 = 53% of the observed decline in the gender wage gap.

Lastly, V_4 is when the full set of our key parameters, τ_g^{FD}, τ_g^{DF}, A_g^F, and A_s^F, changed to the 2004-08 level: $V_4 = V(\Theta_{72}, \tau_{g08}^{FD}, \tau_{g08}^{DF}, A_{g08}^{F}, A_{s08}^{F})$. A decrease in home-to-foreign trade costs works to retain employment in the manufacturing sector. As a result, the increase in the gender wage ratio under V_4 is less than in V_3. It suggests that changes in these four parameters explain 19% of the observed decline in the gender wage gap and 24% of the observed increase in female service employment.

Table 5 breaks down the gender wage ratio into the female wage and the male wage. It shows that the increased gender wage ratio at home is caused by an increase in the female wage and a decline of the male wage. This result is consistent with empirical findings from a reduced-form analysis by Besedeš et al. (2021) where they find that the China trade shock narrowed the gender wage gaps through an increase in female wages and a decrease in male wages. Table 5 also presents wage levels in the foreign country. It shows that trade works to decrease the gender wage ratio by raising the male wage more than the female wage. This result is similar to the

Stolper-Samuelson effect derived from the Heckscher-Ohlin model: an increase in foreign exports of the male-intensive manufacturing good raises the factor price of male labor.

We acknowledge that it is difficult to distinguish the impact of change in trade costs and the impact of change in productivities. The purpose of this exercise is not to give the full picture of the separate impacts of these variables on the gender wage gap. Its purpose is to give a better understanding of the model's mechanisms. To summarize, our central estimate comes from V_4, considering bilateral changes in trade costs and foreign productivity growth. Increased international trade caused by these changes explains about 19% of the closing gender wage gap and 19% of the increase in female service employment.

The remaining decrease of the gender wage gaps may be explained by, for example, firm-level adjustments in technology (e.g., Juhn et al., 2013, 2014), salary payment structures (e.g., Greaney and Tanaka, 2021), labor participation behavior (e.g., Onozuka, 2016), human capital (e.g., Heath and Jayachandran, 2017), or digitization (e.g., Shapiro and Mandelman, 2021). Quantifying the effects of these channels is left for future research.[15]

Table 5: Counterfactuals, decomposing the relative wages

		Model		Counterfactuals			
		68-72	04-08	V_1	V_2	V_3	V_4
		(1)	(2)	(3)	(4)	(5)	(6)
Home							
	Female wages	1.23	2.17	1.25	1.25	1.26	1.26
	Male wages	1.95	2.79	1.79	1.93	1.77	1.91
	Female wage/male wage	0.630	0.779	0.674	0.662	0.695	0.684
Foreign							
	Female wages	1.23	2.41	1.24	1.25	1.28	1.29
	Male wages	1.95	3.09	2.17	2.06	2.27	2.16
	Female wage/male wage	0.629	0.781	0.573	0.606	0.566	0.596

4. Concluding remarks

We have analyzed the effect of international trade on gender gaps by utilizing a theoretical model. The previous study, Ngai and Petrongolo (2017), has shown that a rise in the service sector accounts for one-fifth of the decline in gender gaps in the U.S. during the period

[15] Other potentially important considerations include the introduction of an agricultural sector, more detailed modelling of specific properties of the service sector, the inclusion of the concept of 'tasks', and allowing heterogeneity in skills across workers. While these considerations are certainly important, the current paper attempts to build the simplest model quantifying the link between trade and gender gaps. Furthermore, an application to the Japanese economy would be interesting. These considerations are left for future research.

1968-2008. Building upon their model, this paper has proposed a model where the service employment share changes due to international trade. Our counterfactual analysis suggests that a decrease in trade costs coupled with an increase in foreign productivity are responsible for about one-fifth of the observed decrease in gender gaps during the 1968-2008 period.

Our model helps explain how international trade affects labor market outcomes for each gender through sectoral resource reallocation. Nevertheless, we acknowledge that our estimate is not directly comparable with the one found by Ngai and Petrongolo (2017). International trade affects gender gaps not only through sectoral transformation but also through changes in other endogenous variables. Furthermore, our model includes a foreign country and has additional elements such as monopolistically competitive markets. However, we hope our model clarifies the channel through which trade affects labor market outcomes by gender through this previously less examined structural transformation channel.

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Appendix
Target moments

This section describes detailed expressions of the target moments.

(1) and (2). The service employment share for female and male labor is

$$\frac{L_{ks}^{DD} + L_{ks}^{DF} + L_{ks}^{D\theta}}{\left(L_{kg}^{DD} + L_{kg}^{DF} + L_{kg}^{D\theta}\right) + \left(L_{ks}^{DD} + L_{ks}^{DF} + L_{ks}^{D\theta}\right)} \quad \text{for } k = f, m$$

where L_{ks}^{DD} indicates the amount of type *k* labor employed by domestic firms to produce varieties sold to the domestic market; L_{ks}^{DF} indicates the amount of type *k* labor employed by domestic firms to produce varieties sold to the foreign market; and $L_{ks}^{D\theta}$ indicates the amount of type *k* labor employed to cover fixed costs. The denominator is the sum of labor demands in the two sectors. The numerator is the labor demand in the service sector.

(3) and (4). The hour share for manufacturing work for female and male labor is

$$\underbrace{\frac{L_k - \frac{\xi_{hk}^{\eta_h} w_k^{-\eta_h}}{W_h^{1-\eta_h}} \frac{\beta_h^{\mu} W_h^{1-\mu}}{\Phi^{1-\mu}} \frac{\alpha_z^{\varepsilon} \Phi^{1-\varepsilon}}{\Theta^{1-\varepsilon}} - \varphi \frac{\xi_{lk}^{\eta_l} w_k^{-\eta_l}}{W_l^{1-\eta_l}}}{L_k}}_{Hour\ share\ for\ work} \underbrace{\frac{L_{kg}^{DD} + L_{kg}^{DF} + L_{kg}^{D\theta}}{\left(L_{kg}^{DD} + L_{kg}^{DF} + L_{kg}^{D\theta}\right) + \left(L_{ks}^{DD} + L_{ks}^{DF} + L_{ks}^{D\theta}\right)}}_{Manufacturing\ share} \quad \text{for } k = f, m,$$

The first term is the 'hour share for work' derived from utility maximization of the households. The solution to the consumer optimization problem does not tell us if the time is spent for service work or manufacturing work. Therefore, the first term is multiplied by the second term, which captures the share of demands for *manufacturing* work, to obtain the 'hour share for *manufacturing* work'.

(5) and (6). The hour share for service work for female and male labor is

$$\underbrace{\frac{L_k - \frac{\xi_{hk}^{\eta_h} w_k^{-\eta_h}}{W_h^{1-\eta_h}} \frac{\beta_h^{\mu} W_h^{1-\mu}}{\Phi^{1-\mu}} \frac{\alpha_z^{\varepsilon} \Phi^{1-\varepsilon}}{\Theta^{1-\varepsilon}} - \varphi \frac{\xi_{lk}^{\eta_l} w_k^{-\eta_l}}{W_l^{1-\eta_l}}}{L_k}}_{Hour\ share\ for\ work} \underbrace{\frac{L_{ks}^{DD} + L_{ks}^{DF} + L_{ks}^{D\theta}}{\left(L_{kg}^{DD} + L_{kg}^{DF} + L_{kg}^{D\theta}\right) + \left(L_{ks}^{DD} + L_{ks}^{DF} + L_{ks}^{D\theta}\right)}}_{Service\ share} \quad \text{for } k = f, m.$$

As in (3) and (4), the first term is multiplied by the second term, which captures the share of demands for *service* work, to obtain the 'hour share for *service* work'.

(7). The service expenditure share is

$$\frac{r_s^{DD} N_s^D}{r_s^{DD} N_s^D + r_g^{DD} N_g^D + r_g^{FD} N_g^F}.$$

Here, r_s^{DD} indicates the service revenue earned by each domestic firm from the domestic market, and N_s^D is the mass of domestic service firms. Therefore, the numerator, $r_s^{DD} N_s^D$ is the total revenue earned by domestic service firms from the domestic market. The denominator includes three components, $r_s^{DD} N_s^D$, $r_g^{DD} N_g^D$, and $r_g^{FD} N_g^F$. The first is from the numerator. Second, $r_g^{DD} N_g^D$ is the total revenue earned by domestic manufacturing firms from the domestic market. Third, $r_g^{FD} N_g^F$ is the total revenue earned by foreign firms from the domestic market. As a result, the denominator measures the total expenditure spent by domestic households.

(8). The imports-to-domestic production ratio is

$$\frac{r_g^{FD} N_g^F}{r_s^{DD} N_s^D + r_g^{DD} N_g^D + r_g^{FD} N_g^F}.$$

(9). The exports-to-domestic production ratio is

$$\frac{r_g^{DF} N_g^D}{r_s^{DD} N_s^D + r_g^{DD} N_g^D + r_g^{FD} N_g^F}.$$

(10). The female wages and the male wages are endogenous variables in the computational program. Therefore, the gender wage gap (the female wage rate divided by the male wage rate) is defined by the two endogenous variables.