Globalization, Gender Wage Gap, and Female Labor Force Participation*

Terry Cheung
Academia Sinica†

Paul I. Ko
Dickinson College ‡

Han Yang
Academia Sinica§

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Abstract

In the past several decades, gender wage gap has significantly decreased and female labor force participation has risen in many developed economies. In this paper, we study how international trade affects female and male employment and gender wage gap. We develop a quantitative trade model to study the impact of globalization on the rise of female labor force participation and decrease in the gender wage gap. In our model, we account for two types of competing forces: domestic-driven structural change and trade-induced structural change. Structural change arises not only through asymmetric productivity growth between goods and services sectors but also through the decline in trade costs for the goods sector. In our quantification, we find that when trade costs decrease in the goods sector, this decrease induces a rise in the share of the service sector. The rise in the service sector then raises female workers' relative wages, but without marketization and domestic-driven structural change, female market hours decrease.

Keywords: Trade, structural change, labor force participation, gender gap

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†Institute of Economics, Academia Sinica, e-mail: terrycheung@econ.sinica.edu.tw
‡Department of Economics, Dickinson College, e-mail: kop@dickinson.edu
§Institute of Economics, Academia Sinica, e-mail: hanyang@econ.sinica.edu.tw

1 Introduction

Female labor force participation in the United States has doubled since the 1970s, from 30% in the 1970s to almost 60% in the early 2000s, and gender wage gap has decreased in that time. More women participating in the labor market is not a unique phenomenon in the United States and many developed economies are experiencing a rise in female labor force participation. Recently, researchers and policymakers noted structural change as one of the primary reasons why we observe the rise in female labor force participation. More intuitively, when sectors with higher female shares expand, aggregate female labor force participation will increase, as Stolper-Samuelson theorem suggests. Furthermore, globalization through international trade integration has been one of the primary causes of structural change across countries. Even though there seems to be a link among the increase in globalization, changes in female labor force participation, and the decrease in gender wage gap, we still understand little about how trade-induced structural change affects female labor force participation and gender wage gap.

In this paper, we ask the following question: what is the impact of trade-induced globalization on female labor force participation and gender wage gap? To better understand this relationship, we propose a quantitative trade model that captures how globalization leads to the expansion of the service economy, which in turn, captures the rising relative demand for female market hours and increasing female wages. We find that when trade barriers decrease for the goods sector (an increase in globalization), we find that relative female wages increase by around 4-5% between 1990–2000, and relative female market hours also increase from trade-induced structural change.

Understanding the rise of female labor force participation and the decrease in gender wage gap has become a particularly pressing question in the past several decades. Most of the increase in total labor force participation in the United States was driven by an increase in female labor force participation.[1] However, this is not a phenomenon that we observe only in the United States; we also find that more females have joined labor markets in other OECD countries. This empirical phenomenon has brought a vast interest among researchers and policymakers to uncover the causes and consequences of this global trend. Many have focused on the shocks to the female labor supply. Greenwood et al. (2005) suggests that improvements in home technology, such as the invention of washing machines, have made a significant impact on the rise of female labor force participation. Diebolt and Perrin (2013) discusses how the increase in female bargaining power and female empowerment has led to females participating in the labor market in western countries. On the other hand, some have focused on the changes in the labor market: structural change in the economy. Ngai and Petrongolo (2017) suggests that the rise of the service economy through structural transformation and marketization has helped female labor force participation to rise. However, most of the recent works either focus on the United States economy or do not consider globalization a potential force that could change gender wage gap and demand for female labor in the market.

[1]We observe that male labor force participation in the United States has been decreasing since the 1970s, and therefore, the rise of labor force participation in the United States had been mostly driven by the rise in female labor force participation.

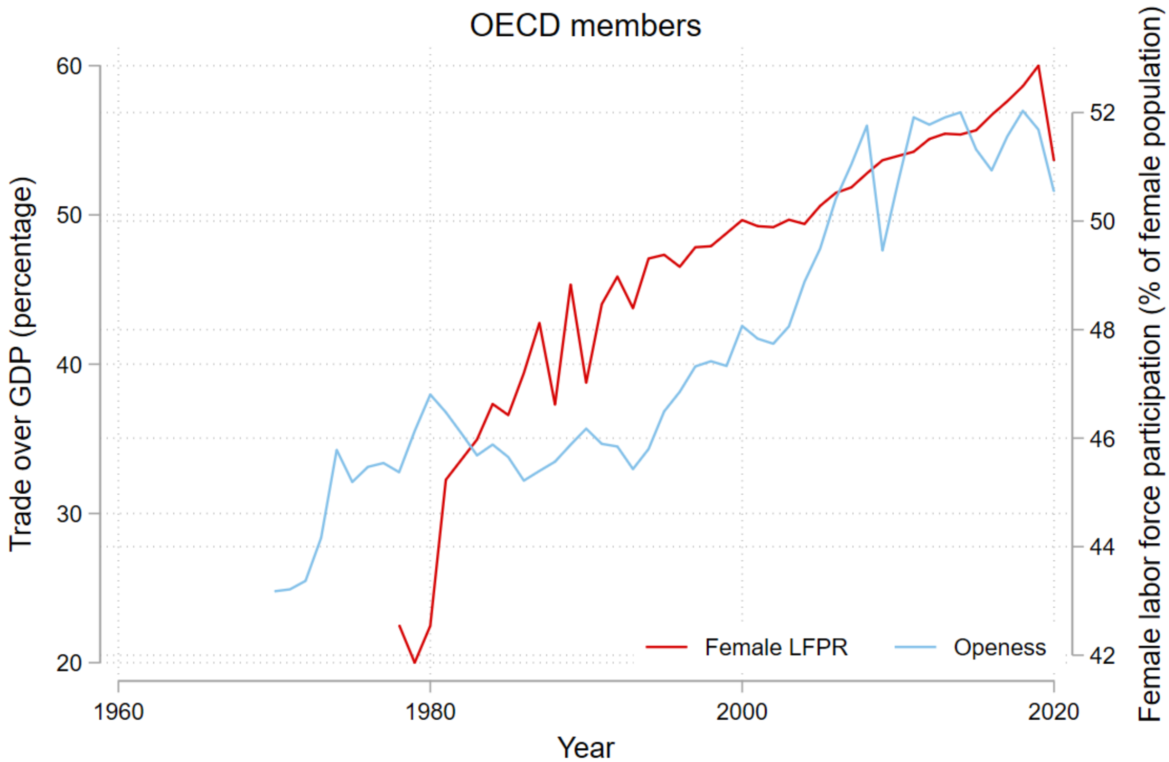

Figure 1: Openness and Female Labor Force Participation

This paper attempts to explain how globalization has affected female labor force participation and gender wage gap in recent decades. Figure 1 plots the correlation between the increase in female labor force participation and trade openness between the 1970s and 2020.[2] As we observe from Figure 1, the rapid increase in female labor force participation from the 1980s in OECD economies is highly correlated with the increase in trade openness. Motivated by this fact, we propose a mechanism in which trade openness induces structural change and, in turn, induces changes to female labor force participation and gender wage gap.

We first document several motivating facts that serve as our starting points for constructing our model. First, we show that higher openness to international trade is positively correlated with higher female employment share for a broad set of developed countries. Second, we document that the goods and service sectors consist of different female and male worker compositions: the services sector is more female-worker intensive, and the goods sector is relatively more male-worker intensive. Third, we observe that countries with a higher degree of trade openness exhibit a faster-growing service sector and a faster-shrinking manufacturing sector. Lastly, we show that the goods sector has higher intermediate intensity when compared to the service sector. The first three observations show that as countries become more economically integrated through trade, their service sector employment shares increase, which induces a higher demand for female

[2]In Figure 1, trade openness is measured as the sum of total trade (exports plus imports) over the sum of GDP in OECD countries.

workers. The last empirical observation tells us that the goods sector is increasingly using more intermediate inputs due to a relative decline in prices of intermediate goods, which in turn, shifts resources toward intermediate inputs away from labor inputs.

Equipped with these empirical observations, we propose a multi-country, two-sector (goods and services) quantitative trade model with two types of labor: female and male labor. International trade is modeled using Eaton and Kortum (2002) structure, where differences in comparative advantages shape trade patterns between countries. When trade patterns are decided globally, each country reallocates its resources, labor and intermediate inputs, between goods and services sectors. We adopt Cravino and Sotelo (2019) by allowing for non-unitary elasticity of substitution between sectors and heterogeneous workers by their gender. On the household side, we carefully adopt the model by Ngai and Petrongolo (2017) to embed home production to allow workers to choose their time allocations between market and non-market (household) activities.

We consider a mechanism that links both domestic-driven and trade-induced structural change to the changes to labor market allocations and wages by gender. The key assumption in our model, just as in the empirical evidence, is that service sectors are relatively more female-worker intensive. In this paper, either increases in goods sector productivity or reduction in trade costs reduce the size of the goods sector and expand the service sector if service sector is relatively more income elastic than goods sector. In other words, this corresponds to the elasticity of substitution across two sectors to be less than one. Then as real income increases, there is an increased demand for service sector compared to goods sector. Furthermore, as intermediate goods prices decline, goods sector shifts toward using intermediate inputs relatively more than labor. This shrinks the goods sector further and therefore, the share of male employment shrinks as well. Since the service sector is more female-intensive, the reduction of the goods sector increases wage premiums for female workers.

We then take the model to the data by calibrating it to the benchmark year of 1990. We match various data moments such as wages and employment shares by genders, producer prices for goods and services, and bilateral goods exports and imports to find a steady-state of our model.

To quantitatively assess our model, we perform several counterfactual exercises. We take asymmetric productivity growth for market goods, market service sectors, and non-market home production sector from the data and Ngai and Petrongolo (2017). We observe that the goods sector grew faster than the service sector (domestic-driven structural change), and the market service sector grew faster than the non-market home production sector (marketization). For trade shocks, we estimate changes in trade costs between 1990 and 2000 following Head and Ries (2001). Then we consider three counterfactual scenarios: (i) both trade and domestic productivity shocks, (ii) trade shocks-only case, and (iii) domestic productivity shocks-only case. For these three counterfactual scenarios, we compare the changes to service shares, changes to relative female wages to male wages (gender wage gap), and changes to relative female market hours.

In our result, we find that the calibrated model predicts about 10 to 25 percent increase in service shares across ten countries, and about half of this rise in service share is due to the decline in trade barriers. We also find that relative female wages have increased by 5 percent, which captures the decrease in gender wage gap across the world. Interestingly, we find that countries, where trade is a larger component of their income, are relatively more affected by trade; trade shocks have a larger impact on relative female wages compared to asymmetric growth in domestic productivity. Furthermore, we find that relative female market hours increase compared to those of males when both trade-induced or domestic-driven structural changes occur. However, domestic-driven structural change affects the relative market hours much more than trade-induced structural change. We conjecture that this may be due to the fact that domestic-driven structural change not only has asymmetric productivity growth in the goods and service sectors but also captures the marketization force away from home production.

Our paper contributes mainly to three strands of literature. First, it contributes to the literature on understanding the increase in female market hours and the decrease in gender wage gap from different macroeconomic perspectives. Many papers have looked into the changes to female labor force participation and the decrease in gender wage gap from the labor demand side.[3] This paper builds on Ngai and Petrongolo (2017) and Dinkelman and Ngai (2021), where they emphasize that the rise of the service sector in the United States had a large impact on the rise of female labor force participation and decrease in gender wage gap. In their work, they discuss how domestic-driven structural change causes female labor force participation to rise due to higher female labor demand. In our paper, we focus on the impact of trade-induced structural change on female market hours and female market wages.

Several papers look at the relationship between international trade and gender. Hakobyan and McLaren (2018) uses firm-level data to find that NAFTA tariff reductions (increase in trade integration) are associated with reductions in wage growth for blue-collar female workers. Another empirical work by Bonfiglioli and De Pace (2021) finds that increases in firms' exports increase gender wage gap for blue-collar workers and decrease it for white-collar workers. Keller and Utar (2022) studies how the impact of China shock affects women's biological clock of having children, which impacts their labor market choices. To the best of our knowledge, Juhn et al. (2013), Juhn et al. (2014), and Sauré and Zoabi (2014) study the impact of trade on female labor market conditions through the lens of a general equilibrium model.

Our paper brings in a new insight into how trade affects female labor force participation and gender wage gap. Following the works of Eaton and Kortum (2002) and Cravino and Sotelo (2019), reallocation of labor arises due to comparative advantages of different countries when there is an increase in trade integration. Since service sector is more income elastic, when trade barriers in the goods sector decrease and intermediate goods prices fall, labor demand in the service sector increases as countries shift their resource allocations. This trade-induced structural change is further amplified by domestic-driven, asymmetric productivity growth between the goods, service, and home production (non-market) sectors. Therefore, our framework allows us to do a horse race between two types of structural change forces: domestic-driven versus trade-induced structural changes.

Secondly, we contribute to the literature on the impact of structural change in open-economy macroeconomics. Matsuyama (2009) finds that understanding the productivity growth in the manufacturing sector and the decline in manufacturing employment should be studied in open economies. Uy et al. (2013) and Fajgelbaum and Redding (2022) study the effects of trade-induced structural change in the cases of South Korea and Argentina, respectively. Święcki (2017) argues that changes to sectoral productivities are the main driver of structural change in most countries. Perhaps the closest work to ours is Cravino and Sotelo (2019), where they find that trade-induced structural change had a large impact on the rise of skill premium

[3] There also have been important works from the labor supply side. Greenwood et al. (2005) looks at improvements in home technology, such as washing machines, which have freed female hours, which in turn, have had an impact on the rise of female labor force participation. Albanesi and Olivetti (2009), Goldin and Olivetti (2013), and Dinkelman and Ngai (2021) look at how changes to home production time affect female labor earnings and the gender wage gap.

in the United States. We contribute to this literature by discussing how trade-induced structural change affects gender inequality — by incorporating endogenous trade imbalances and modeling asymmetric trade costs á la Eaton and Kortum (2002) to study the implications of how sectoral re-allocations by gender would affect gender inequality in developed economies.

Finally, we contribute to the burgeoning literature on multi-country quantitative trade models. Parro (2013) and Burstein and Vogel (2017) examine how capital-skill complementarity affects skill premium in different countries. Cravino and Sotelo (2019) builds a more parsimonious industry-sectoral model to study across-sector labor reallocations. In our work, we focus on gender wage premium and labor reallocation by gender and connect the quantitative trade model by explicitly modeling home production and leisure choices, in spirit of Ngai and Petrongolo (2017). In our paper, we can further consider how market versus non-market (home) productions are affected by trade-induced structural change.

The rest of the paper proceeds as follows. In Section 2, we document various empirical facts on the relationship between trade, structural change, and employment by gender. Section 3 discusses the quantitative trade model that captures how domestic and trade-induced structural changes affect relative female market hours and relative wages. In Section 4, we discuss how we take the endogenous outcomes of the model to the data. We present our main findings through several counterfactual exercises in Section 5, and the Section 6 concludes the paper.

2 A First Look at the Data

This section documents the cross-sectional patterns between 1990 and 2010 using the data from the World Bank Database. First, we show that countries with higher openness to international trade tend to have a higher portion of female employment. Second, we find that the service sector is more female-intensive when compared to the manufacturing sector. Third, we document that not only does the service sector grow in absolute and relative (to manufacturing) terms, but its expansion is faster in countries with higher openness to international trade. Finally, we use World Input-Output Table to show that the manufacturing sector has higher intermediate intensity than the service sector.

2.1 Openness and Female Employment Share

Figure 1 shows the positive correlation between openness and female labor participation in the OECD countries. Figure 2 confirms such a pattern using cross-country data of OECD countries in 2010. It shows that a country with higher total trade relative to GDP ratio also has higher female employment relative to that of males. It is summarized in the following observation.

OBSERVATION 1: Countries with higher openness to international trade also have a higher portion of female employment.

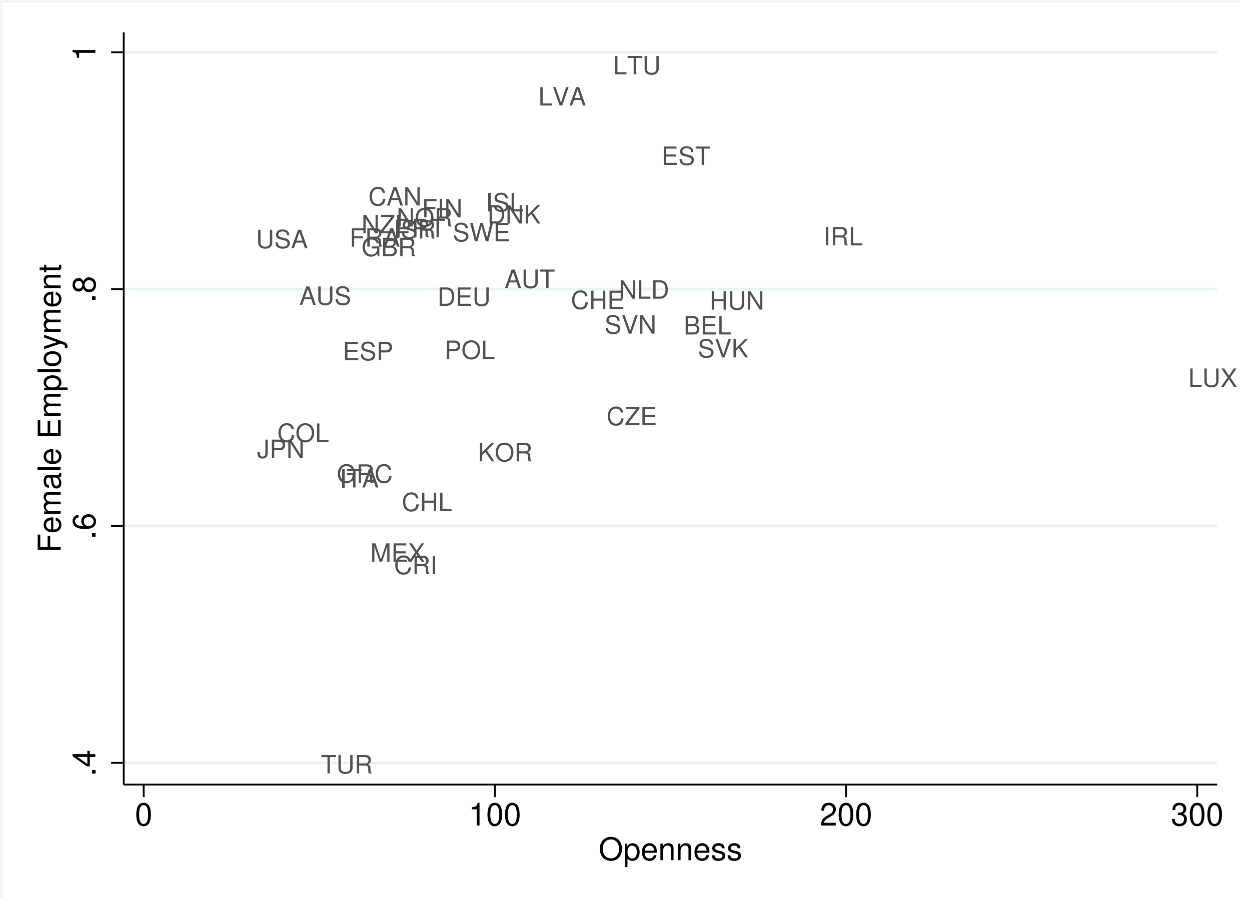

Figure 2: Female Employment Share and Openness. Source: World Bank

2.2 Change in Sectoral Employment Share and Female Intensity

We now report how female intensities vary across different sectors and the change in the relative size of these sectors across the OECD countries. Analogous to Cravino and Sotelo (2019), the sectoral female intensity is defined as the share of female employment in a particular sector relative to the share of male employment in that sector.[4]

Figure 3 plots the sectoral female intensity and the 1990-2010 changes in sectoral employment share for different OECD countries. The figure reveals that the goods sector, which has lower female intensity, declines; while the service sector, which has higher female intensity, expands. Moreover, there is also a positive (and significant) correlation between sectoral female intensity and the change in sectoral employment share across these two sectors. So, a country-sector pair that has higher female intensity also expands more between 1990 and 2010. These are summarized in the following observation.

OBSERVATION 2: Services sector, which has higher female intensity ($L_s^f/L_s^m > L^f/L^m$), expands; and

[4] So the female intensity in sector $j \in \{g, s\}$ is $(L_j^f/L^f)/(L_j^m/L^m)$ where $L^f = \sum_j L_j^f$ and $L^m = \sum_j L_j^m$.

goods sector, which has lower female intensity ($L_g^f/L_g^m > L^f/L^m$), shrinks. Country-sector pairs with higher female intensity expand faster.

Figure 3: Female Intensity and Sectoral Labor Allocation. Source: World Bank

2.3 Change in Sectoral Employment Share and Openness

Third, in order to have a better understanding of the relationship between female employment and countries' openness to trade, we report the correlation between openness and sectoral employment share. Figure 4 plots the 1990-2010 changes in sectoral employment share and openness for different OECD countries. The figure shows that the service sector expands faster with international trade while the manufacturing sector declines faster with international trade. Since the service sector has higher female intensity (Observation 2), the expansion in the service sector leads to an increase in female employment. These are summarized in the following observation.

OBSERVATION 3: Countries with higher openness to international trade have a faster-growing service sector and a faster-shrinking manufacturing sector.

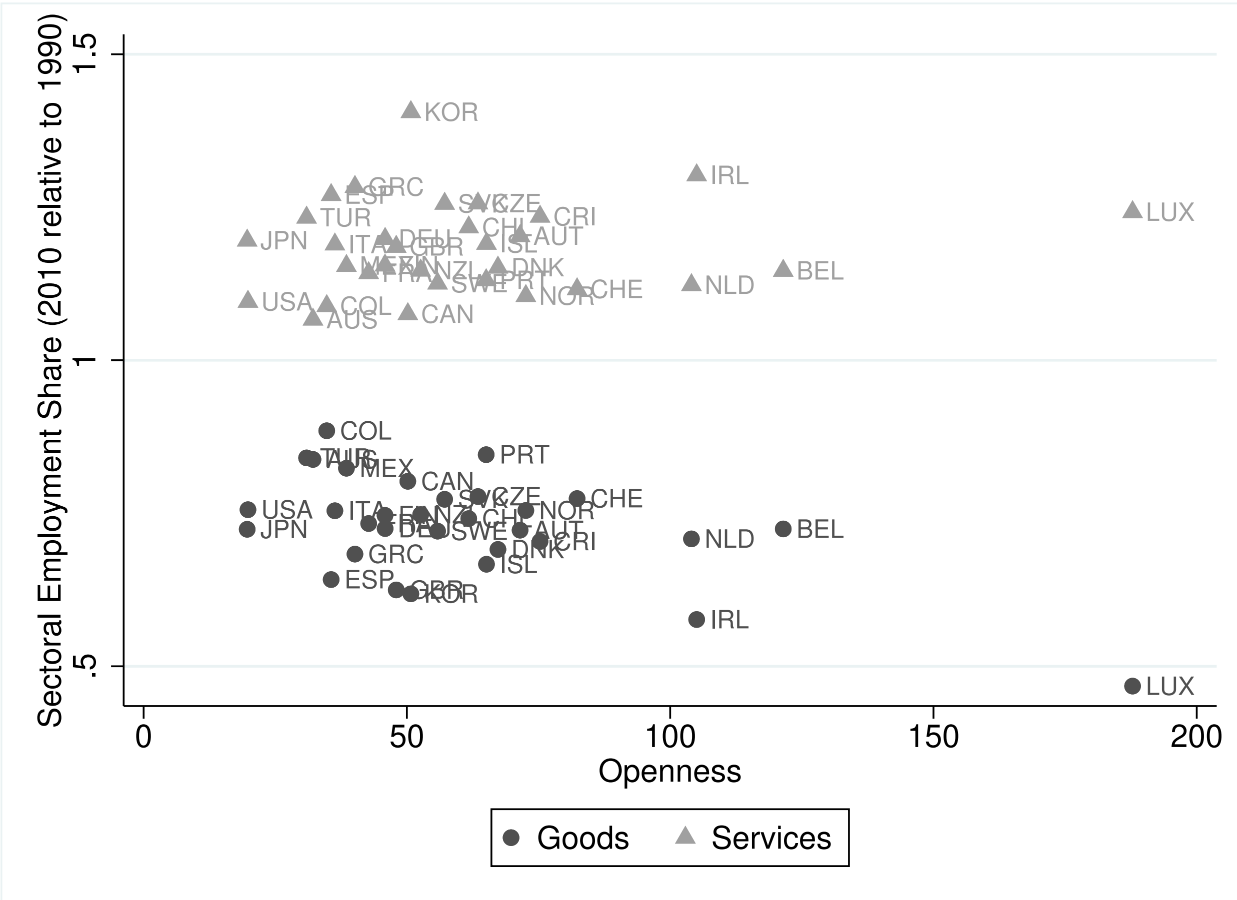

Figure 4: Openness and Sectoral Labor Allocation. Source: World Bank

2.4 Change in Sectoral Employment Share and Openness

Finally, we report the intermediate input share in the goods and service sector. Figure 5 reports the 1990 intermediate input share in goods and service sectors. The figures show that the goods sector has higher intermediate intensity when compared to the services sector. So, in countries with higher openness to international trade, the goods sector experiences more reduction in intermediate price.

OBSERVATION 4: Goods sector has higher intermediate intensity when compared to the services sector.

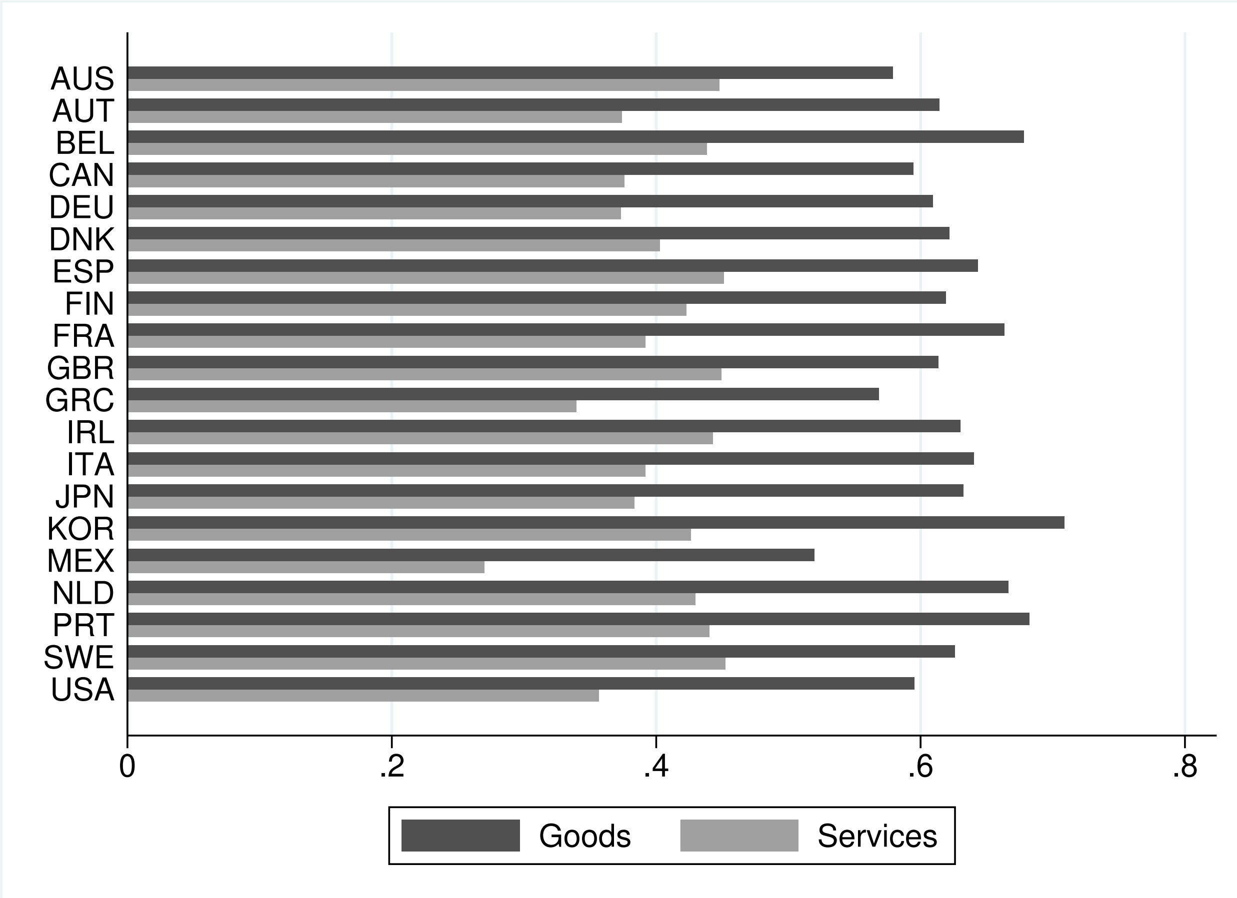

Figure 5: Intermediate Intensity in Manufacturing and Services Sectors. Source: WIOD

2.5 Summary of Data

The data in this section show that the more female-intensive service sector experienced an expansion in employment share between 1990 and 2010, while the less female-intensive goods sector experienced a decline. In addition, the degree of expansion in the service sector and the decline in the goods sector correlate with countries' openness. This leads to a positive correlation between openness and female labor employment. Since the goods sector has higher intermediate intensity than the services sector, in countries with higher openness to international trade, the goods sector experiences more reduction in intermediate goods price. This also leads to further shrinking goods sector employment because the labor is substituted by intermediate goods.

3 Model

In this section, we construct a multi-country general equilibrium trade model that captures linkages between trade, structural change, and relative market hours and wages of female and male workers. The model is driven by two comparative advantage aspects: (i) comparative advantage across countries and (ii) comparative advantage across workers between females and males within a country. We adopt Cravino and Sotelo (2019) for modeling the production side and add Ngai and Petrongolo (2017)'s features for the supply side of the economy.

3.1 Environment

We consider an economy with N countries indexed by $i, n \in \{1, \ldots, N\}$. Each country is endowed with L_i amount of labor, which consists of female labor ($L_{i,f}$) and male labor ($L_{i,m}$). Each country consists of three sectors: (i) goods (g), (ii) services (s), and (iii) home production (h), and each sector is indexed by $j \in \{g, s, h\}$.There is also a continuum of varieties of goods and services indexed by $\omega^j \in [0,1]$. While goods and services are traded across countries, home production is not tradable. We also assume perfect competition in all markets, and international trade is modeled following Eaton and Kortum (2002).

3.2 Production

3.2.1 Production of Market Goods and Services

Producers of intermediate market goods and services varieties ω^j in sector j in country i produce output with the following constant elasticity of substitution technology:

$$q_i^j(\omega^j) = A_i^j z_i^j(\omega^j)\left(\left[\xi^j[L_{i,f}^j(\omega^j)]^{\frac{\eta^j-1}{\eta^j}} + (1-\xi^j)[L_{i,m}^j(\omega^j)]^{\frac{\eta^j-1}{\eta^j}}\right]^{\frac{\eta^j}{\eta^j-1}}\right)^{\alpha_i^j}\left(\prod_{j'\in\{g,s\}}(M_i^{j'j})^{\gamma_i^{j'j}}\right)^{1-\alpha_i^j}, \quad (1)$$

using female labor $L_{i,f}^j(\omega^j)$ and male labor $L_{i,m}^j(\omega)$ for sector j in country i, and the bundle of intermediate inputs $M_i^{j'j}$ coming from sector j'. We denote η^j to be the parameter that governs the elasticity of substitution across female and male labor inputs. Input-output shares are determined by the inner Cobb-Douglas parameter $\gamma_i^{j'j}$, where $\sum_{j'\in\{g,s\}}\gamma_i^{j'j} = 1$ for each country i. We define the factor shares of female and male labor in the production with α_i^j.

We define A_i^j as the aggregate total factor productivity in sector j in country i, and $z_i^j(\omega^j)$ is country-sector-variety specific productivity, which is drawn from a Fréchet distribution following Eaton and Kortum (2002)

$$\Pr(z_i^j(\omega) < z) = \exp(-T_i^j z^{-\theta^j}). \quad (2)$$

Finally, ξ^j denotes the relative productivity parameter for female labor working in sector j. We make a crucial assumption that $\xi^s > \xi^g$, where female workers have a comparative advantage in the service sector than working in the goods sector.

3.2.2 Final Production of Tradable Varieties

Production of each tradable sector j aggregates the production of all of its varieties $\omega^j \in [0,1]$ via constant elasticity of substitution (CES) aggregator

$$Y_i^j = \left[\int_0^1 y_i^j(\omega^j)^{\frac{\sigma-1}{\sigma}} d\omega\right]^{\frac{\sigma}{\sigma-1}}. \tag{3}$$

where $y_i^j(\omega^j)$ denotes absorption of ω^j variety in sector j in country i. Then these variety-specific absorption variables are aggregated via CES production function, with constant elasticity of substitution parameter σ.

3.2.3 Non-tradable Home Production

We consider home production as a type of "service" product that is not tradable. Home production also utilizes female and male labor as factor inputs to produce Q_i^h, which is defined using an aggregate CES function

$$Q_i^h = A_i^h \left[\xi^h (L_{i,f}^h)^{\frac{\eta^h-1}{\eta^h}} + (1-\xi^h)(L_{i,m}^h)^{\frac{\eta^h-1}{\eta^h}}\right]^{\frac{\eta^h}{\eta^h-1}}, \tag{4}$$

where η^h is the elasticity of substitution parameter between female and male labor in home production. A_i^h is the aggregate total factor productivity for home production in country i, and η^h is the relative productivity parameter for females in producing home services.

3.2.4 Firm Optimization

We turn to the optimal decisions by firms. Assuming that markets are perfectly competitive, we can calculate a free-on-board price for variety ω^j for market production sectors for each variety $\omega^j \in [0,1]$.[5] If variety ω^j is produced in country i, then the free-on-board (f.o.b) price should be equal to its marginal cost $\frac{c_i^j}{z_i^j(\omega^j)}$, where

$$c_i^j = \left(c_i^{L,j}\right)^{\alpha_i^j} \left(p_i^{M,j}\right)^{1-\alpha_i^j}. \tag{5}$$

The unit cost bundle for market production sector j consists of two parts: factor input cost bundle $c_i^{L,j}$ and the intermediate price index $p_i^{M,j}$. The intermediate price index is

$$p_i^{M,j} = \left(p_i^g\right)^{\gamma_i^{gj}} \left(p_i^s\right)^{\gamma_i^{sj}}, \tag{6}$$

which is a Cobb-Douglas bundle of intermediate prices of goods p_i^g and services p_i^s. The factor input cost bundle $c_i^{L,j}$ is defined as

$$c_i^{L,j} = \left[(\xi^j)^{\eta^j}(w_{i,f})^{1-\eta^j} + (1-\xi^j)^{\eta^j}(w_{i,m})^{1-\eta^j}\right]^{\frac{1}{1-\eta^j}}. \tag{7}$$

[5]Since the services sector is not traded, f.o.b price is simply equal to the domestic price.

As we noted before, there are two types of labor inputs, where $w_{i,f}$ and $w_{i,m}$ denote female and male wages, respectively.

To derive payments to female and male workers, we first define $Y_i^j(\omega^j)$ to be the total output of a particular variety producer ω_i^j. From the first-order conditions for firms' profit maximization problem, we can obtain the variety-specific payments that female and male labor receive:

$$w_{i,f}L_{i,f}^j(\omega^j) = (\xi^j)^{\eta^j}\left(\frac{c_i^j}{w_{i,f}}\right)^{\eta^j-1} Y_i^j(\omega^j) \tag{8}$$

$$w_{i,m}L_{i,m}^j(\omega^j) = (1-\xi^j)^{\eta^j}\left(\frac{c_i^j}{w_{i,m}}\right)^{\eta^j-1} Y_i^j(\omega^j) \tag{9}$$

Aggregating the above equations at the sector level, we can define the share of payments to female labor as

$$s_{i,f}^j \equiv (\xi^j)^{\eta^j} \times \left(\frac{c_i^j}{w_{i,f}}\right)^{\eta^j-1} \tag{10}$$

and the share of payments to male labor as

$$s_{i,m}^j \equiv (1-\xi^j)^{\eta^j} \times \left(\frac{c_i^j}{w_{i,m}}\right)^{\eta^j-1}. \tag{11}$$

We note that the shares of payments to female and male labors are endogenous to the unit cost bundles and their own respective wages. This is the key mechanism in which both domestic and trade-induced structural change can affect the gender wage gap and gender-specific labor force participation.

3.3 Households

For the household, we carefully follow and adapt Ngai and Petrongolo (2017) for their modeling choices. There is a representative household that consists of a woman and a man.[6] They jointly determine how much to spend on market goods and services (c_i^g and c_i^s), how much hours should be devoted to home production ($L_{i,f}^h, L_{i,m}^h$) which determines consumption level of home production (c_i^h), and how much hours should be devoted to leisure ($L_{i,f}^\ell, L_{i,m}^\ell$). The utility function is defined as

$$U_i = (1-\phi)\ln C_i + \phi \ln L_i^\ell \tag{12}$$

where ϕ is the Cobb-Douglas parameter between consumption and leisure. Consumption C_i in each country i is defined as

$$C_i = \left[\psi\left(C_i^g\right)^{\frac{\varepsilon-1}{\varepsilon}} + (1-\psi)\left(C_i^z\right)^{\frac{\varepsilon-1}{\varepsilon}}\right]^{\frac{\varepsilon}{\varepsilon-1}}, \tag{13}$$

[6]To simplify our modeling assumptions, we only focus on different-sex households, and abstract from considering single or same-sex households.

where C_i is a CES aggregation of goods consumption C_i^g and a service-bundle consumption C_i^z. We define ψ as a relative preference parameter for household goods consumption and ε as the constant elasticity of substitution parameter between goods and services consumption. We further assume that goods and services are poor substitutes ($\varepsilon < 1$).

Now we define the service-bundle consumption. The service-bundle consumption C_i^z is defined as

$$C_i^z = \left[\zeta\left(C_i^s\right)^{\frac{\rho-1}{\rho}} + (1-\zeta)\left(C_i^h\right)^{\frac{\rho-1}{\rho}}\right]^{\frac{\rho}{\rho-1}}, \tag{14}$$

which is another CES bundle that consists of the home service C_i^h and the market service C_i^s. We define ζ to be the relative preference parameter for market service consumption, and ρ is a constant elasticity of substitution between market service and home service. We further make an assumption that market and home services are good substitutes ($\rho > 1$).

Home service consumption C_i^h comes from home production, and since we assumed that home production is non-tradable services, we can write

$$C_i^h = Q_i^h = A_i^h\left[\xi^h[L_{i,f}^h]^{\frac{\eta^h}{\eta^h-1}} + (1-\xi^h)[L_{i,m}^h]^{\frac{\eta^h}{\eta^h-1}}\right]^{\frac{\eta^h}{\eta^h-1}}. \tag{15}$$

Leisure time L_i^l is another CES aggregate of female and male leisure times:

$$L_i^\ell = \left[\xi^\ell[L_{i,f}^\ell]^{\frac{\eta^\ell}{\eta^\ell-1}} + (1-\xi^\ell)[L_{i,m}^\ell]^{\frac{\eta^\ell}{\eta^\ell-1}}\right]^{\frac{\eta^\ell}{\eta^\ell-1}} \tag{16}$$

where ξ^l is a relative preference parameter for leisure time for females. We assume that $\eta^l < 1$, which notes that female and male leisure hours are poor substitutes.

3.3.1 Household Optimization

The optimization problem of a representative household in country i is to maximize (12) by choosing the aggregate consumption levels for market goods C_i^g, market services C_i^s, non-market home production services C_i^h, and female and male leisure time allocations $L_{i,f}$, and $L_{i,m}$, subject to the following budget constraint:

$$P_i^g C_i^g + P_i^s C_i^s = w_{i,f}[L_{i,f} - L_{i,f}^h - L_{i,f}^\ell] + w_{i,m}[L_{i,m} - L_{i,m}^h - L_{i,m}^\ell]. \tag{17}$$

Here, we choose the world income as a numéraire, which requires the following condition to hold:

$$\sum_{i=1}^{N}\left(w_{i,f}[L_{i,f} - L_{i,f}^h - L_{i,f}^\ell] + w_{i,m}[L_{i,m} - L_{i,m}^h - L_{i,m}^\ell]\right) = 1. \tag{18}$$

This is a standard normalization that is needed to identify the levels of output, expenditures, and trade flows between countries, shown by Allen et al. (2020). Therefore, this normalization implies that all results will be in terms of global income.

3.4 Converting the Household's Problem

Solving for the optimal choices of household is not straightforward in this model. Therefore, instead of using Lagrangian to meticulously derive all the first-order conditions, we take a different approach in our paper. The only difference between non-tradable home production and leisure sectors and tradable goods and services sectors is that the costs are implicit for non-tradable sectors. Using the first welfare theorem, we can re-write the household's problem so that there are competitive brokers for home production and leisure. Then, the equilibrium allocation under this duality setting would coincide with the allocation we solve using the Lagrangian. In this section, we describe how we use this duality to solve for optimal home production and leisure prices.

We first rewrite the household's optimization problem as if leisure and home production are competitive and traded domestically. Given $\{P_i^g, P_i^s, P_i^h, P_i^\ell\}$, the household's optimization problem becomes

$$\max_{\{C_i^g, C_i^s, C_i^h, C_i^\ell\}} \left(\left[\psi \left(C_i^g\right)^{\frac{\varepsilon-1}{\varepsilon}} + (1-\psi)\left(C_i^z\right)^{\frac{\varepsilon-1}{\varepsilon}} \right]^{\frac{\varepsilon}{\varepsilon-1}} \right)^{1-\phi} \left(L_i^\ell\right)^{\phi} \tag{19}$$

subject to the following constraints:

$$C_i^z = \left[\zeta \left(C_i^s\right)^{\frac{\rho-1}{\rho}} + (1-\zeta)\left(C_i^h\right)^{\frac{\rho-1}{\rho}} \right]^{\frac{\rho}{\rho-1}}, \tag{20}$$

$$P_i^g C_i^g + P_i^s C_i^s + P_i^h C_i^h + P_i^\ell C_i^\ell = w_{i,f} L_{i,f} + w_{i,m} L_{i,m}. \tag{21}$$

Since brokers for home production and leisure sectors are competitive, the implicit market prices of home production and leisure satisfy

$$P_i^h = \frac{c_i^h}{A_i^h} = \frac{\left[(\xi^h)^{\eta^h} (w_{i,f})^{1-\eta^h} + (1-\xi^h)^{\eta^h} (w_{i,m})^{1-\eta^h} \right]^{\frac{1}{1-\eta^h}}}{A_i^h}, \tag{22}$$

$$P_i^\ell = c_i^\ell = \left[(\xi^\ell)^{\eta^\ell} (w_{i,f})^{1-\eta^\ell} + (1-\xi^\ell)^{\eta^\ell} (w_{i,m})^{1-\eta^\ell} \right]^{\frac{1}{1-\eta^\ell}}. \tag{23}$$

Here, we note that the implicit price indices for home production and leisure depend on the relative productivity parameters of females in each sector and the elasticity of substitution between the two genders. Productivity for home production A_i^h will play a crucial role when we take the model to the data, where we will allow for faster growth in market sectors.

From this household optimization, we can derive the following expenditure shares:

$$e_i^\ell = \phi \tag{24}$$

$$e_i^g = (1-\phi) \times (\psi)^\varepsilon \left(\frac{P_i^C}{P_i^g} \right)^{\varepsilon-1} \tag{25}$$

$$e_i^s = (1-\phi) \times (1-\psi)^\varepsilon \left(\frac{P_i^C}{P_i^z} \right)^{\varepsilon-1} \times (\zeta)^\rho \left(\frac{P_i^z}{P_i^s} \right)^{\rho-1} \tag{26}$$

$$e_i^h = (1-\phi) \times (1-\psi)^\varepsilon \left(\frac{P_i^C}{P_i^z} \right)^{\varepsilon-1} \times (1-\zeta)^\rho \left(\frac{P_i^z}{P_i^h} \right)^{\rho-1} \tag{27}$$

where P_i^C and P_i^z denote price indices for the consumption bundle and the bundle of market and non-market (home production) services, respectively:

$$P_i^C = \left[(\psi)^\varepsilon (P_i^g)^{1-\varepsilon} + (1-\psi)^\varepsilon (P_i^z)^{1-\varepsilon}\right]^{\frac{1}{1-\varepsilon}} \tag{28}$$

$$P_i^z = \left[(\zeta)^\rho (P_i^s)^{1-\rho} + (1-\zeta)^\rho (P_i^h)^{1-\rho}\right]^{\frac{1}{1-\rho}} \tag{29}$$

Then we can write the total expenditures of consumption for each sector $j \in \{g, s, h, \ell\}$:

$$X_i^j \equiv P_i^j C_i^j = e_i^j (w_{i,f} L_{i,f} + w_{i,m} L_{i,m}) \quad \forall j \in \{g, s, h, \ell\}. \tag{30}$$

3.5 International Trade

We assume that only market goods are traded internationally. To trade a unit of tradable market goods from origin country i to destination country n, $\tau_{in}^j > 1$ units need to be produced in sector j.[7] Trading domestically, on the other hand, is costless, and we assume that $\tau_{ii}^j = 1$ for all i. If $j = s$, we let $\tau_{in}^j = \infty$, which guarantees that services will not be traded.

We need to determine bilateral trade flows between countries i and n. To achieve this, we first need to construct the unit cost of producers of a variety ω^j in country i that can potentially sell in country n, c_{in}^j:

$$c_{in}^j(\omega^j) = \frac{c_i^j \tau_{in}^j}{A_i^j z_i^j(\omega^j)} \tag{31}$$

where we can observe that this unit cost of producers differs by country-pairs and by sector due to the iceberg trade cost τ_{in}^j. Firms then source tradable ω^j in sector j from the lowest-cost suppliers, which is denoted by

$$p_n^j(\omega^j) = \min_i \left\{ c_{in}^j(\omega^j) \right\} = \min_i \left\{ \frac{c_i^j \tau_{in}^j}{A_i^j z_i^j(\omega^j)} \right\}. \tag{32}$$

We denote sectoral price indices as

$$P_i^j = \Gamma\left(\frac{\theta^j - 1 + \sigma}{\theta^j}\right) \left[\Phi_i^j\right]^{-\frac{1}{\theta^j}}, \tag{33}$$

which can be derived from Eaton and Kortum (2002). Given equations (32) and (33), we can derive bilateral trade flows between countries i and n. The share of total expenditures in sector j in country n in goods produced by country i is defined as

$$\pi_{in}^j = \frac{T_i^j \left[\left(\frac{c_i^j}{A_i^j}\right) \tau_{in}^j\right]^{-\theta^j}}{\sum_{m=1}^N T_i^j \left[\left(\frac{c_m^j}{A_m^j}\right) \tau_{mn}^j\right]^{-\theta^j}} = T_i^j \left(\frac{c_i^j \tau_{in}^j}{A_i^j P_n^j}\right)^{-\theta^j}. \tag{34}$$

Equation (34) is considered "shares" as if we sum them across the origin countries i, we obtain $\sum_{i=1}^N \pi_{in}^j = 1$

[7] This is standard iceberg trade cost assumption in international trade literature.

for tradable sector j.

3.6 Market Clearing

There are several market clearing conditions that need to be satisfied in the equilibrium. First, we need the world's sectoral market clearing condition - the total output of sector j equal to the total sectoral demand j globally. By denoting Y_i^j to be the gross value of the output of country i in sector j, we write the world's industry market clearing condition to be

$$Y_i^j = \begin{cases} \sum_{n=1}^{N} \pi_{in}^j X_n^j, & \text{for } j \in \{g\} \\ X_i^j, & \text{for } j \in \{s, h, \ell\} \end{cases} \tag{35}$$

Equation (35) states the sectoral market clearing for both tradable and non-tradable. For sectors that are tradable, the world's supply of tradable goods sector is equal to the world's demand for that sector. However, for market services (s), leisure (ℓ), and home production (h) sectors, the value of gross output is equal to the total expenditure, as everything country i produces is consumed domestically.

Second, each country's female and male labor markets need to clear:

$$w_{i,f} L_{i,f} = s_{i,f}^j \sum_{n=1}^{N} \pi_{in}^j X_n^j + s_{i,f}^s X_i^s + s_{i,f}^h X_i^h + s_{i,f}^\ell X_i^\ell \tag{36}$$

$$w_{i,m} L_{i,m} = s_{i,m}^j \sum_{n=1}^{N} \pi_{in}^j X_n^j + s_{i,m}^s X_i^s + s_{i,m}^h X_i^h + s_{i,m}^\ell X_i^\ell. \tag{37}$$

Equations (36) and (37) state that the value of total labor supplied for females and males should be equal to the sum of the value of total labor demanded in each sector.

4 Taking the Model to Data

To conduct counterfactual analyses to understand the impact of domestic-driven versus trade-induced structural changes, we need to match the endogenous outcomes of the model to the data and determine the key parameters. In this section, we discuss how we determine the model's key parameters and data sources, and how we calibrate the key model outcomes to the data.

4.1 Key Parameters of the Model

First, we discuss the key parameters that we take from the data and other sources. We take the factor share of market production (α_i^j) and input-output share in market production ($\gamma_i^{j'j}$) from the World Input-Output Database (WIOT). We take the relative productivity parameter for female labor, ξ^j, in sector j's production from Ngai and Petrongolo (2017). We let $\xi^g = 0.29$, $\xi^s = 0.43$, $\xi^h = 0.5$, and $\xi^\ell = 0.29$. This tells us that women have relatively the highest comparative advantage in home production ($\xi^h = 0.5$). Comparing goods and services, women have a higher comparative advantage in the services sector ($\xi^s =$

Parameters	Description	Value	Source
$\alpha^j, j \in \{g, s\}$	Factor Share in Market Production	-	WIOD
$\gamma_i^{j'j}, j \in \{g, s\}$	Input-output Share in Market Production	-	WIOD
$\xi^j, j \in \{g, s, h, \ell\}$	Relative Productivity Parameter for Female Labor	-	Ngai and Petrongolo (2017)
$\eta^j, j \in \{g, s, h, \ell\}$	Elasticity of Substitution b/t Female & Male in Production	-	Ngai and Petrongolo (2017)
σ	Trade Elasticity	2.7	Broda and Weinstein (2006)
ψ	Relative Preference for goods	0.5	Ad Hoc (for now)
ζ	Relative Preference for market services	0.5	Ad Hoc (for now)
ε	Elasticity of Substitution b/t Goods and Service Bundle in Consumption	0.002	Herrendorf et al. (2013)
ρ	Elasticity of Substitution b/t Home and Market Services in Consumption	2	Aguiar et al. (2012)

Table 1: Key Parameters of the Model

0.43) compared to the goods sector ($\xi^g = 0.29$). We also observe this from the relative gender wage and hours ratio in the data.

Given the relative productivity parameters, we also need to determine the elasticity of substitution between women and men, η^j, in each sector $j \in \{g, s, h, \ell\}$. We also take these elasticities from Ngai and Petrongolo (2017), where $\eta^g = \eta^s = \eta^h = 2.27$ and $\eta^\ell = 0.29$. These numbers are obtained by matching responses in hours ratio (home and leisure) to changes in wage ratio. Furthermore, we set the trade elasticity $\sigma = 2.7$, which is taken from Broda and Weinstein (2006). This value determines the Fréchet dispersion parameter, which then determines the strength of comparative advantage between different countries.

For the elasticity of substitution parameters in the utility function, we take the values from the existing literature. For the elasticity of substitution between goods and services bundle in consumption, we choose $\varepsilon = 0.002$, which is borrowed from Herrendorf et al. (2013). They estimate the elasticity using micro-level household consumption data and relative prices and find that goods and services are near-perfect substitutes. For the elasticity of substitution between home and market services, we choose the value of $\rho = 2$, which is taken from Aguiar et al. (2012) and Rogerson and Wallenius (2016). They use micro-level data on consumer expenditure and home production hours in households to estimate this elasticity. [8]

4.2 Matching Endogenous Outcomes of the Model

We also need to match several endogenous outcomes of the model to the data to back out domestic productivity and trade shocks. In this section, we carefully describe which endogenous variables are matched with the data moments. The endogenous outcomes in the model that we match with the data are: (i) wages by gender ($w_{i,f}$ and $w_{i,m}$); (ii) sectoral employment by gender ($L^j_{i,f}$ and $L^j_{i,m}$ for $j \in \{g, s\}$); (iii) household expenditure shares on goods and services (e^j_i for $j \in \{g, s\}$) in each country; and (iv) share of country n's absorption imported from country i in sector j (π^j_{in} for $j \in \{g, s\}$).

Wages. Matching wages by gender was challenging due to data limitations. We use the median annual wages by gender data from the International Labour Organization Department of Statistics (ILOSTAT), the US Bureau of Economic Analysis (BEA) and using the gender wage gap in the OECD Structural Analysis (STAN). Some countries' data on wages by gender are missing, so we estimate them using the data on the gender wage gap. Details on the estimation and extrapolation procedures are listed in the appendix.

[8]There are other papers such as Rupert et al. (1995) and Gelber and Mitchell (2012) which give similar estimates to what we use in this paper.

Sectoral Employment by Gender. We take the sectoral employment of goods and services by gender from the International Labour Organization (ILOSTAT) database.

Household Expenditure Shares. We estimate the household expenditures from matching producer prices for goods and services, using equations (24), (25), (26), and (27). Since we cannot calculate household expenditure shares on home production and leisure, we do not match expenditure shares directly from the data; instead, we estimate the expenditure shares using the equilibrium conditions from our model. We match producer price indices (PPI) for goods and services from the World Input-Output Database (WIOD). We normalize the price index for home production (P_i^h) to be 1, and match the price index for market services with the PPI for service sector from the data. Furthermore, by estimating the price index for goods by matching the PPI for goods sector, we can calculate (24), (25), (26), and (27).

Trade Shares. We directly match bilateral import trade shares for the goods and services sectors from the WIOD. Bilateral import shares, π_{in}^j are the expenditure of country n in imports coming from origin country i in sector j, as a share of total expenditure in country n. So π_{in}^j can be defined as

$$\pi_{in}^j \equiv \frac{X_{in}^j}{X_n^j} \tag{38}$$

where X_{in}^j is country n's imports arriving from origin country i in sector j and X_n^j is the total expenditure of country n in sector j. We obtain total expenditure by subtracting net exports from gross output of country n in sector j, Y_n^j. More details of how we calculate import trade shares are in the appendix.

5 Quantitative Analyses

This section answers how domestic-driven structural change versus trade-induced structural change affects female labor force participation and the gender wage gap in our model. First, we discuss how we obtain international trade shocks – modeled as iceberg trade costs – and asymmetric productivity shocks. Then, we conduct two counterfactual exercises to measure these effects: (i) no trade shocks; and (ii) no productivity shocks. After the two counterfactuals, we interpret the results by comparing them with our benchmark quantification. We conclude this section with the sensitivity analyses of our model with different parameters. (ON-GOING)

5.1 Trade-Induced vs. Domestic-Driven Structural Change

5.1.1 Productivity Shocks

We take productivity shocks directly from the literature. Using borrow productivity growth for market goods, market services, and home production from Ngai and Petrongolo (2017). Labor productivity growth for market sectors is obtained from the Bureau of Economic Analysis (BEA). BEA reports that labor productivity growth for the market goods sector has been 2.49%, while the market services sector's growth rate is

1.25%. For home production, we take the numbers from Bridgman et al. (2012) and Bridgman (2016), where we set the growth rate for home production productivity to be 0.45%.

We emphasize that these different growth rates between market goods, market services, and non-market home production sectors are crucial in analyzing our mechanism. When productivity for the goods sector grows faster than the service sector, the relative price for service sector production will become more expensive. However, since market goods and services are good complements, this increases market hours and expenditure towards the service sector. This channel increases the share of services in the economy, which captures the domestic-driven structural change. Secondly, we also assumed that market service sector productivity growth is faster than non-market (home production) service productivity. Since market services and home-produced goods are substitutes, workers (particularly female workers) would substitute away from home production to market goods and services – this is a marketization force that is also discussed in Ngai and Petrongolo (2017).

5.1.2 Trade Shocks

We obtain bilateral trade shocks by measuring changes in bilateral trade costs from changes in bilateral expenditure shares, where we follow the approach by Head and Ries (2001). We start from the derivation of the bilateral import shares (34). To derive the Head-Ries style of trade shocks, we first convert (34) for the goods sector ($j = g$) using the hat-algebra approach suggested by Dekle et al. (2007),

$$\widehat{\pi}_{in}^{g} = \widehat{T}_{i}^{g} \left(\frac{\widehat{c}_{i}^{g} \widehat{\tau}_{in}^{g}}{\widehat{A}_{i}^{g} \widehat{P}_{n}^{g}} \right)^{-\theta^{g}}, \tag{39}$$

where a hat over a variable denotes the ratio between the final period's variable and the benchmark year's variable, $\widehat{x} = \frac{\widehat{x}_{t+1}}{\widehat{x}_{t}}$. Then, taking the ratio of (39) with the domestic shares $\widehat{\pi}_{ii}^{g}$, and recognizing that $\widehat{\tau}_{ii}^{g} = 1$, we obtain

$$\widehat{\tau}_{in}^{g} = \left(\frac{\widehat{\pi}_{in}^{g}}{\widehat{\pi}_{ii}^{g}} \right)^{-\frac{1}{\theta^{g}}} \left(\frac{\widehat{P}_{n}^{g}}{\widehat{P}_{i}^{j}} \right) \tag{40}$$

To perform our counterfactuals, we consider a case when there is a unilateral, symmetric trade cost reduction across the world. We take the symmetric trade cost reduction because we want to isolate the effect of an increase in trade integration without a particular country's trade shock dominating the other trade shocks. Therefore, by assuming that $\widehat{\tau}_{in}^{g} = \widehat{\tau}_{ni}^{g}$, we can obtain the Head-Ries trade shock:

$$\widehat{\tau}_{in}^{g} \widehat{\tau}_{ni}^{g} = \left[\frac{\widehat{\pi}_{in}^{g} \widehat{\pi}_{ni}^{g}}{\widehat{\pi}_{ii}^{g} \widehat{\pi}_{nn}^{g}} \right]^{-\frac{1}{\cdot}\theta^{g}} \tag{41}$$

Using the Head-Ries trade shocks equation (41) and matching the changes in import shares between country i and n and the changes to domestic shares in the two countries, we estimate the changes to trade shocks between the benchmark and final years. Our steady-state initial year is 1990, and the final year is 2000.

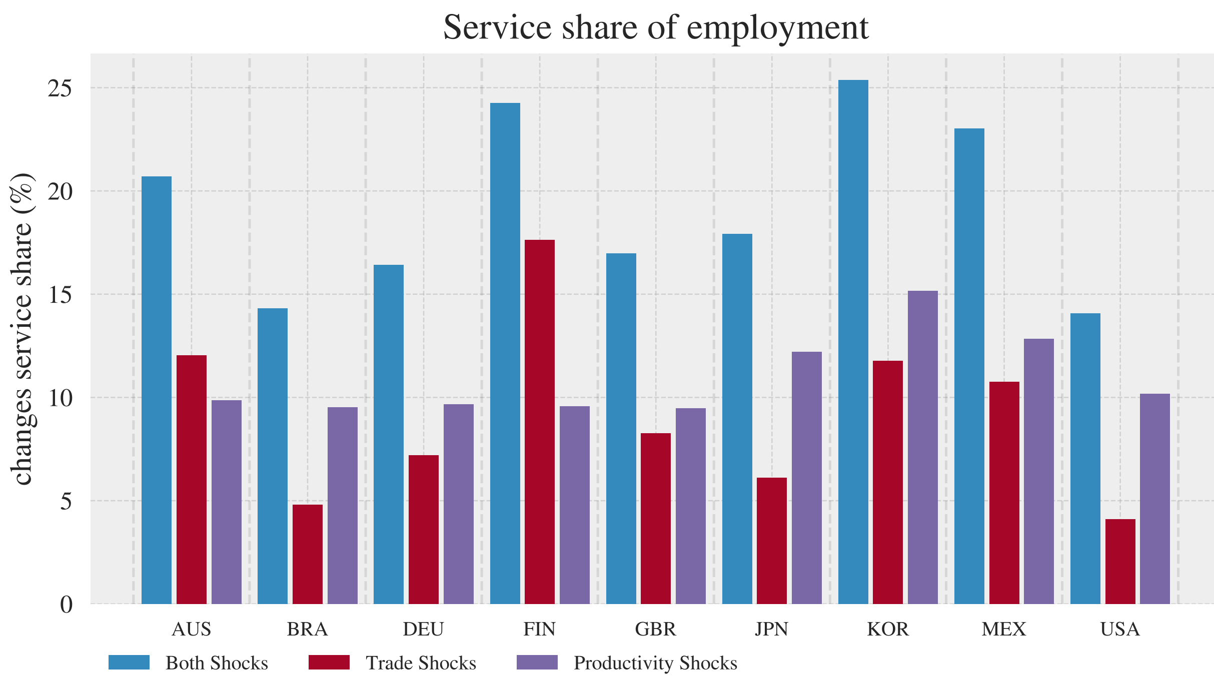

Figure 6: Changes in Services Sector Share

5.2 Main Results

Our quantitative results compare the benchmark case where we activate both trade-induced structural change and domestic-driven structural change shocks. We call the following the *benchmark calibration*: calibration with feeding in estimated trade shocks and asymmetric productivity shocks from Ngai and Petrongolo (2017). To compare how each of these forces individually affects the gender wage gap and female market hours, we consider the following counterfactual exercises and compare the results with the *benchmark calibration*: we fix one particular shock to be constant at the initial year of 1990 while feeding in the other shock. This allows us to isolate the effect of one particular shock on endogenous outcomes such as female and male wages, their market hours, and also trade shares between country pairs.

Service Shares. Figure 6 compare the counterfactual changes in service share of employment when we consider both asymmetric productivity shocks and trade shocks combined and also when we only consider one shock at a time. In general, when both trade and domestic productivity shocks are at play, we observe that the service sector share in all countries increases by 10% to 25%. Australia, Finland, South Korea, and Mexico experienced significant service sector expansions, while the United States was slightly below 15%. This result is not surprising since the United States had a relatively higher share of the service sector prior to the 1990s than other economies.

Figure 6 also shows the effects of two counterfactual scenarios. “Trade Shocks” refers to a counterfactual scenario when we only feed in symmetric trade shocks while fixing productivity shocks as constant in 1990 levels. “Productivity Shocks” scenario refers to a counterfactual scenario when we only feed in domestic

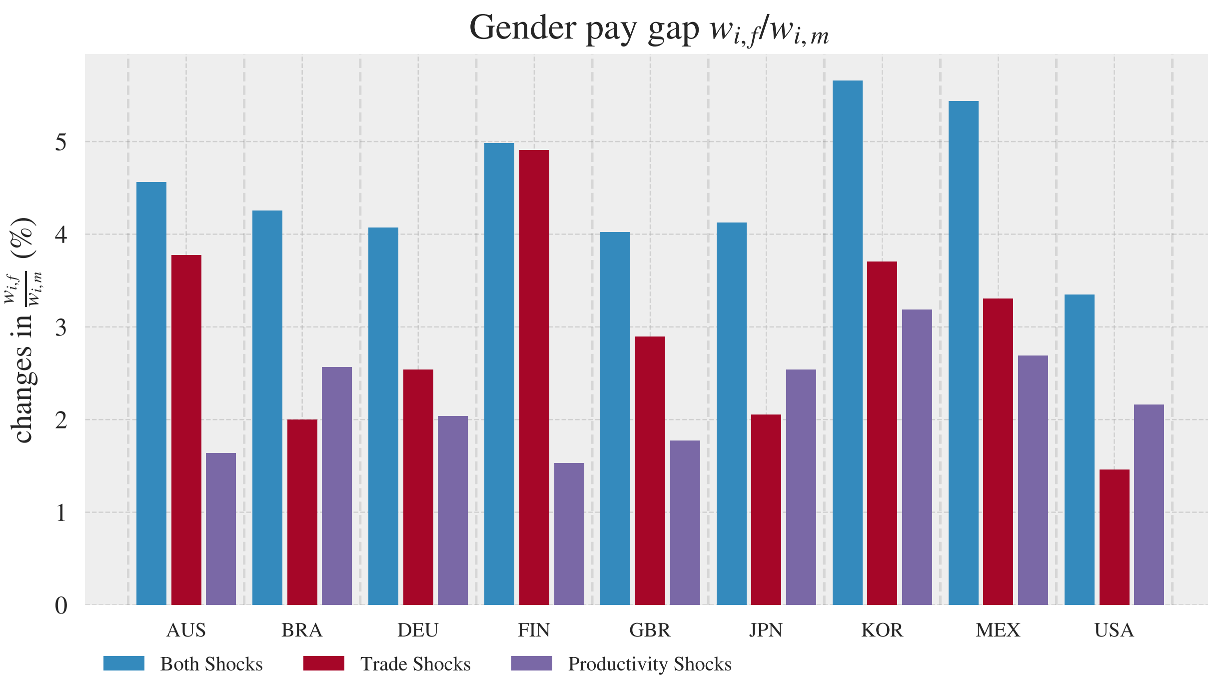

Figure 7: Changes in Gender Wage Gap

productivity shocks while fixing trade shocks to be constant in 1990 levels. As we observe from Figure 6, the impact of trade and productivity shocks are heterogeneous across countries. In countries such as the United States, Brazil, and Japan, we find that the changes in service shares were primarily driven by asymmetric productivity shocks between market goods and service sectors. This finding is intuitive since the countries mentioned above are relatively closed economies.

Relative Female Wages. Figure 7 presents changes in relative female wages, or female-to-male wage ratio, $\frac{w_{i,f}}{w_{i,m}}$, in each country. This statistic can be interpreted that, the higher the relative female wage ratio, the lower the gender wage gap in that particular country. In our benchmark scenario, we find that the relative female wages increased between 1990 and 2000, where see an average of around 4% increase in relative female wages. In our counterfactual scenario where we only consider shocks to trade, we still observe that all countries experience an increase in relative female wages: trade-induced structural change has a significant impact on decreasing gender wage gap across the developed economies. The impact of trade-induced structural change is particularly large for Australia and Finland — the overall increase in relative female wages in those countries is mostly driven by trade-induced structural change. For the United States, trade cost reductions have a modest increase in relative female wages, which is around 1%. We further observe that changes in relative female wages depend on countries' economic size and trade openness.

When we consider a counterfactual case with productivity shocks only, we find that the result flips from the trade shock-only scenario. In countries such as Australia and Finland, domestic productivity shocks are not the primary driver of the changes in relative female wages. However, for the United States, asymmetric domestic productivity growth is a larger component in the changes to relative female wages.

Relative Female Market Hours. Figure 8 depicts the changes in relative female-male market hours between 1990 and 2000. Overall, the market hours ratio between female and male workers increases in all countries in the data. Australia and Finland, once again, experienced the largest changes in the relative female market hour ratio. Overall, the average of the ten countries in our dataset resorts to around a 5% increase in relative female market hours. Relative female market hours increased by around 4% in the United States, which is on the lower end compared to the other countries in our dataset.

We find more interesting results when we consider our counterfactual scenarios: looking at the impact of trade and productivity shocks separately. Figure 8 shows that relative female market hours have increased in most countries. Furthermore, we find that the large changes in the relative female market hours ratio in Australia and Finland come from the larger impact of trade shocks. Great Britain, South Korea, and Mexico had moderate increases in the market hours ratio for females. For Japan and the United States, we do not observe significant changes in relative female market hours – domestic productivity growth has a much larger impact than trade shocks.

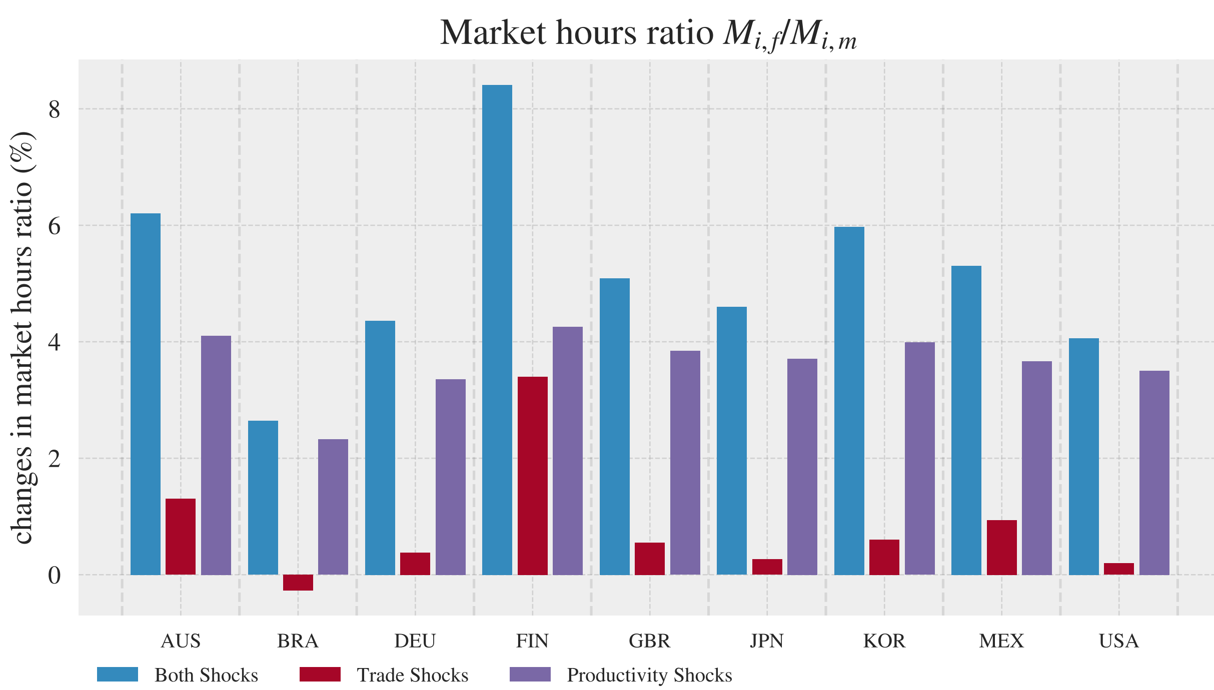

Figure 8: Changes in Relative Female-Male Market Hours

6 Conclusion

Changes in female labor force participation and gender wage gap are positively correlated with trade openness. In this paper, we developed a quantitative trade model with market and non-market (home) sectors to disentangle the impacts of trade-induced structural change and domestic-driven structural change affecting gender wage gap and relative female market hours. We find that the changes in trade patterns (trade-induced structural change) have had a significant impact on decreasing the gender wage gap since the 1990s — changes in relative female wages have increased by 3–4% between 1990 and 2000 by shocks to trade. This is also highly correlated with the rise in service shares in countries in our dataset. About half of changes in service shares across countries are explained by the decline in trade costs for the goods sector due to the differing income elasticities across goods and service sectors, which induces a rise in relative female wages and their relative market hours. We further find that the increase in the relative female wages is higher in relatively more open economies.

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A Data Description

A.1 Female and Male Wages

We use the median annual wages by gender data from the International Labour Organization Department of Statistics (ILOSTAT), the US Bureau of Economic Analysis (BEA), and using the data on gender wage gap in the OECD Structural Analysis (STAN). In this subsection, we discuss how each country's female and male wages have been determined.

Countries	Method
Australia (AUS)	Data & Estimated
Brazil (BRA)	Data
Chile (CHL)	Data
Germany (DEU)	Data & Estimated & Extrapolated
Finland (FIN)	Data & Estimated
United Kingdom (GBR)	Data & Estimated
Japan (JPN)	Data & Estimated
South Korea (KOR)	Data & Estimated & Extrapolated
Mexico (MEX)	Data & Estimated & Extrapolated
New Zealand (NZL)	Data & Estimated
United States (USA))	Data
Rest of the World (ROW)	Data & Estimated

Table 2: List of Countries & Wage Determination

Estimation Procedure. For some countries listed above, ILOSTAT does not publish separate female and male annual median wages but only reports aggregate annual median wages. Therefore, we use the aggregate annual median wages and gender wage gap data from the OECD Structural Analysis (STAN) Database to estimate female and male wages.

From OECD STAN Database, gender wage gap is defined as a difference between male and female median wages over the male median wages.

$$gap_i \equiv \frac{w_{i,f} - w_{i,m}}{w_{i,m}} \tag{42}$$

Re-arranging the equation above, we can re-write female wage in terms of the gender wage gap and male wage for each country:

$$w_{i,f} = w_{i,m}\big(1 - gap_i\big). \tag{43}$$

Now we use the following equation

$$w_i L_i = w_{i,f} L_{i,f} + w_{i,m} L_{i,m}, \tag{44}$$

which states that the total compensation should be equal to the sum of female and male workers' compensation. Plugging in equation (43) into the equation above, we obtain

$$w_i L_i = w_{i,m} L_{i,m} (2 - gap_i) \tag{45}$$

Re-arranging, we obtain male wages in country i:

$$w_{i,m} = \frac{w_i L_i}{(2 - gap_i) L_{i,m}} \tag{46}$$

Equation (46) allows us to obtain male workers' annual median wages in country i by matching the following data moments: median annual wages (w_i), total employment (L_i), male employment ($L_{i,m}$), and gender wage gap (gap_i). Then, we can obtain female annual median wages by calculating equation (43).

Extrapolation Procedure. Female and male wages from Germany, South Korea, and Mexico have been further interpolated by plotting a linear trend with existing data. The existing data was only available up to 1992, and female and male wages in 1990 have been extrapolated.

A.2 Trade Shares

We obtain bilateral trade shares from World Input-Output Database (WIOD). Calculating trade shares is more involved, as we need a 2-dimensional matrix, by origin and destination country-pair. Each time period, country n has imports coming in from other i countries (including itself, the domestic shares). And these are in "import shares," so each row of the matrix has to sum up to 1.

Let's consider a 3-country example. If we have Canada, USA, and the rest of the world, the trade share matrix in a particular year will be

$$\begin{bmatrix} \pi_{CANCAN} & \pi_{USACAN} & \pi_{ROWCAN} \\ \pi_{CANUSA} & \pi_{USAUSA} & \pi_{ROWUSA} \\ \pi_{CANROW} & \pi_{USAROW} & \pi_{ROWROW} \end{bmatrix} = \begin{bmatrix} 0.50 & 0.30 & 0.20 \\ 0.05 & 0.70 & 0.25 \\ 0.02 & 0.10 & 0.88 \end{bmatrix} \tag{47}$$

where π_{USACAN} is defined as the share of total Canadian imports that originates from the United States. (U.S. is the origin country, and Canada is the destination.) The rows must sum upto 1.

If we have n countries, each time period, we would have $(n \times n)$ matrix. Then we need to construct a $(n \times n)$ matrix for the import trade shares.

A.2.1 Detailed Description of Calculating Import Trade Shares

We take both bilateral exports and imports of manufacturing to calculate import shares for each bilateral country-pairs. Denoting the amount of imports that country n receives from country i as $X_{in,t}^{IMP,g}$, where the superscript IMP represents "imports" and the superscript "g" represents merchandised tradable goods (manufacturing). Net exports of goods sector for each country are calculated using the total exports and imports of country n in goods sector

$$NX^g_{n,t} = X^{EXP,g}_{n,t} - X^{IMP,g}_{n,t} \tag{48}$$

Equipped with data for gross production in manufacturing goods ($Y^G_{n,t}$), I can calculate total domestic absorption of tradable goods by

$$X^g_{n,t} \;=\; Y^g_{n,t} - NX^G_{n,t} \;=\; Y^g_{n,t} - X^{EXP,g}_{n,t} + X^{IMP,g}_{n,t} \tag{49}$$

which satisfies the global goods market clearing condition. To calculate bilateral import shares, I take the ratio between country n's imports from country i over the total absorption (expenditure) of country n

$$\pi^g_{in,t} = \frac{X^{IMP,g}_{in,t}}{X^g_{n,t}} \tag{50}$$

To complete the import trade share matrix, I need to calculate country n's *own* (domestic) absorption, which is the gross production of goods that are consumed domestically. I denote this as $X^g_{nn,t}$, and can be calculated using

$$X^g_{nn,t} = Y^g_{n,t} - X^{EXP,g}_{n,t} \tag{51}$$

Therefore, country n's own share is

$$\pi^g_{nn,t} = \frac{X^g_{nn,t}}{X^g_{n,t}} \tag{52}$$

This allows us to have $\sum_{i=1}^N \pi^g_{ni,t} = 1$.

B Computational Algorithm