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ABSTRACT

Female Employment and Structural Transformation*

Two prominent secular trends characterize the transformation of labor markets in industrialized countries in recent decades. First, employment has shifted from manufacturing to services. Second, the share of female employment in total employment has risen sharply. This paper documents a novel fact linking these two trends: female employment shares within manufacturing and within services have remained virtually constant over time and across developed economies. Constant sectoral gender shares imply that an exogenous increase in female labor supply can by itself induce structural change. We provide empirical evidence for the presence of this effect in the data. We then propose a quantitative theory of structural change with nonhomothetic preferences, differential sectoral productivity growth, gender complementarity in sectoral production, and rising female employment, and calibrate it to the U.S. economy. Quantitatively, we find that the rise in female employment accounts for about two-thirds of structural change in the U.S. over the past five decades.

JEL Classification:

Keywords: structural change, female employment, labor markets

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1 Introduction

In this paper, we present evidence and develop a theory that connects two of the most prominent labor market developments in industrialized countries in recent decades – the structural transformation, i.e., a decline in manufacturing employment accompanied by an increase of employment in services, and a contemporaneous large increase in female employment. While the previous literature suggested that structural change can induce an increase in female employment, our empirical evidence and quantitative theory highlight the opposite direction of causality: the reallocation of employment from manufacturing to services was largely due to the increased labor force participation of women.

To reach this conclusion, we proceed in four steps, with each of which is a contribution to the existing literature.

1. Nature of Structural Transformation. It is typical in the literature to group industries into "goods producing" and "service producing" and to study the reallocation of economic activity from the former to the latter group.[1] Looking directly at the industries as defined by the standard industrial classification system, we find that structural change was highly concentrated in just two of them. Specifically, we find a very large decline in the employment share of manufacturing, where manufacturing is a separate category in the 2-digit industrial classification. At the same time, there was a large increase in the employment share of the service industry, which includes professional and related services (such as health and education), business and repair services, personal services, and entertainment and recreation services. Employment in all other industries, such as construction, transportation, wholesale and retail trade, finance, insurance, and real estate, mining, etc., has remained virtually constant as a share of the economy over the past 50 years. We document below that this pattern is apparent not only in the US data, but also in the sample of other highly developed economies. This suggests that for the purpose of analyzing structural change, it is helpful to consider three industrial sectors – manufacturing, services, and "Other" – the sector that includes the rest of the economy.

2. Constant Gender Shares in Manufacturing and Services over Time. This partitioning of industries reveals a surprising pattern. While manufacturing employment has declined significantly over the years, the gender share of manufacturing employment has remained constant over the past 50 years, with women accounting for 30% of manufacturing employment. Interestingly, a similar pattern describes the services sector, which has seen a dramatic increase in employment over the years. Women account for 62% of employment in services, a share that has remained unchanged over the past five decades. Women's share of employment in the

[1] This is the type of structural change relevant to the highly developed countries that we study in this paper. Earlier in their development, the decline of agriculture was also a prominent feature of structural change.

Other sector changes over time, co-moving with the economy-wide share of female employment. Remarkably, we observe a similar pattern across a broad sample of developed economies, not only qualitatively but also quantitatively, with the female share of employment fixed over time at 30% in manufacturing and 62% in Services, and moving in tandem with the economy-wide share of female employment in the Other sector.

3. Female Labor Force Participation – a Driving Force of Structural Change? The constancy of female shares in manufacturing and services over time and across developed countries hints at an intriguing possibility. In order to accommodate an exogenous increase in the number of female labor force participants while keeping female employment shares in manufacturing and services constant, employment in the female-intensive service sector must expand while it must contract in the male-intensive manufacturing sector.[2] This is just an application of the classic Rybczynski theorem in a two-sector economy. The presence of the Other sector may in theory affect this logic, but we show below that this is not the case due to strong restrictions from the data: the employment share of the Other sector is roughly constant and its female employment share is parallel to the aggregate economy.

We proceed to test this conjecture empirically. As a first step, we consider a panel of U.S. states and regress the share of manufacturing (or services) employment in the state on the share of female employment in the state. To identify exogenous variation in female labor supply, we construct several instruments for the female employment share at the state level that affect female labor supply but do not directly affect the industrial structure. For all instrument specifications, we find that an exogenous (to the industrial structure) increase in the female employment share leads to a decrease in the manufacturing employment share and an increase in the services employment share. Estimating similar instrumental variable regressions in a panel of developed economies corroborates the results for the United States.

The implications are even stronger when we run the same regressions but with the level of manufacturing (or services) employment as the dependent variable, and the level of female employment as the independent variable, while also controlling for overall employment growth using male employment. We find that an exogenous increase in aggregate female employment reduces manufacturing employment not only as a share of the economy, but also in absolute terms. This dramatically restricts the set of theories that can be used to interpret the relation-

[2] To see this, consider an economy with two sectors, manufacturing m and services s. Market clearing requires that $(N-N_s)f_m+N_sf_s=L_f$, where N is total employment, $N-N_s=N_m$ and N_s are the employment of the manufacturing and service sectors, f_m and f_s are the female employment shares in these two sectors, and L_f is the overall female employment. Dividing both sides by total employment, we have $(1-n_s)\,f_m+n_sf_s=\ell_f$, where $1-n_s=n_m$ and n_s are the manufacturing and service employment shares, and ℓ_f is the overall female employment share. Thus, $\frac{\mathrm{d}n_s}{\mathrm{d}\ell_f}=\frac{1}{f_s-f_m}>0$ and $\frac{\mathrm{d}n_m}{\mathrm{d}\ell_f}=\frac{\mathrm{d}1-n_s}{\mathrm{d}\ell_f}=\frac{-1}{f_s-f_m}<0$ because $f_s=0.62>0.30=f_m$.

ship between female employment and structural transformation.[3,4]

4. Quantitative Theory Evaluation. In order to quantify the role of increased female employment in determining the extent of the structural change and to verify whether the proposed mechanism is consistent with other salient features of the data (such as the dynamics of sectoral prices and value added, gender wage premium, etc.), we consider a competitive multi-sector model with male and female workers.

Based on our empirical findings, we model male and female workers as perfect complements in the manufacturing and services production functions. Disciplined by the observed evolution of gender ratios in the rest of the economy in the data, we allow for time-varying gender employment shares in the Other sector. The model allows for two standard forces of structural change, namely the income effect (due to non-homothetic preferences) and differential sectoral productivity growth. In addition, the model introduces a novel third force that leads to structural change, arising from the increase in female labor force participation.

The calibrated quantitative model with non-homothetic preferences, differential sectoral productivity growth, and rising female employment is successfully accounts for all empirical patterns of structural change, including the paths of sectoral prices, value added, employment, and gender composition. Moreover, the model endogenously delivers a substantial decline in the gender-wage gap over time, consistent with the data. The model thus provides a suitable laboratory to decompose the contribution of each of the three forces to structural change. We find that the rising female employment accounts for about two-thirds of the structural transformation, measured as the reallocation of employment from manufacturing to services.

1.1 Related literature

We contribute to the literature that explores the relationship between structural change and female employment. Ngai and Petrongolo (2017) emphasize that structural change and the rise in female employment tend to be studied in separate literatures, although the two phenomena

[3]Suppose women have a comparative advantage in services. An exogenous increase in female labor force participation would then increase the size of the service sector and reduce the size of the manufacturing sector as a share of the economy. But it is unlikely to reduce the absolute size of the manufacturing sector: an increase in female employment will tend to make female labor cheaper, increasing the female-to-male employment ratio in both sectors and expanding employment in both sectors. This will not happen, however, if male and female workers must be hired in essentially fixed proportions in the two sectors, i.e., if the gender ratios are fixed over time.

[4]In Appendix I.5, we provide some empirical evidence on the opposite direction of causality, i.e., that a decline in the price of manufactured goods leads to an expansion of the service sector and higher female employment. Specifically, we follow the approach of Autor, Dorn and Hanson (2013) and find that a decline in the price of manufacturing goods due to the increased import competition from China neither led to an increase in the service sector employment nor that it induced a higher female labor force participation.

might be related. Specifically, they argue that structural change has increased the demand for female market work because women have a comparative advantage in service production. The rising demand for service workers induced an increase in female labor force participation. A similar demand-side mechanism was studied by Olivetti (2014) and Olivetti and Petrongolo (2014, 2016). We do not dispute the relevance of this mechanism, but identify the importance of causality running in the opposite direction, i.e., that structural change is itself a consequence of rising female labor force participation.

There is a large literature that studies the secular increase in female labor supply over time, including, among others, Goldin (2006), Greenwood, Seshadri and Yorukoglu (2005), Albanesi and Olivetti (2016), Galor and Weil (1996), Attanasio, Low and Sánchez-Marcos (2008), and Fernández (2013). We do not contribute to this literature *per se*, but use its insights to rationalize some of the forces inducing the increase in female employment that our theory predicts to be a necessary condition for structural change.

With respect to the structural transformation literature, Herrendorf, Rogerson and Valentinyi (2014) provide a systematic discussion of the theory and facts of structural transformation. Our primary contribution to this literature is to identify female labor force participation as a novel and quantitatively important driver of the structural change in developed economies. Our work also differs from the tradition in this literature in that we abstain from an ex-ante allocation of industries into sectors (e.g., goods and service producing) and instead group industries according to their change in employment shares over time. This reveals the striking patterns in sectoral gender shares that are the basis of the paper's argument.

The mechanism that explains the narrowing of the gender wage gap is similar in our paper and in Ngai and Petrongolo (2017), although it is quantitatively much stronger in our model. The mechanism is an application of the Stolper-Samuelson theorem which predicts that the rise in the relative price of services increases the return to the factor used intensively the production of services, which is female labor.

Finally, this paper relates to various applications of the Rybczynski (1955) insight that an increase in the supply of a factor leads to the expansion of the sector intensive in that factor. For example, Caselli and Coleman II (2001) propose that human capital growth induces the labor force to move out of the unskilled agricultural sector and into the skilled nonagricultural sector. Acemoglu and Guerrieri (2008) argue that capital deepening results in an increase in the relative output of the more capital intensive sectors. Burstein et al. (2020) study the labor market effects of immigration, allowing for the Rybczynski effect that factors reallocate to immigrant-intensive occupations in response to immigration. In this paper, we show that the rise in female employment leads to a structural transformation from manufacturing (male-intensive) to services (female-intensive).

The rest of the paper proceeds as follows. Section 2 describes the data sources and presents the empirical analysis. Section 3 presents the model, calibrates it to the U.S. economy, and presents the counterfactual simulations. Section 4 concludes.

2 Empirical Analysis

Our empirical analysis first provides results on structural change for three countries for which we have access to rich annual data – the United States, Germany, and France. We find that these three countries share strikingly similar pattern of structural change in employment which is limited to just two narrowly defined manufacturing and service industries, which themselves have essentially fixed gender shares across time and across countries. We then broaden our analysis to countries that are among the 25 countries with the highest GDP per capita in 1970 and which have their periodic population Census data in IPUMS International data set and find the same patterns. Finally, we provide direct empirical evidence suggesting that an exogenous (to the sectoral composition) increase in female employment induces a rise in services and a decline in manufacturing employment.

2.1 The Nature of Structural Transformation and Sectoral Gender Shares

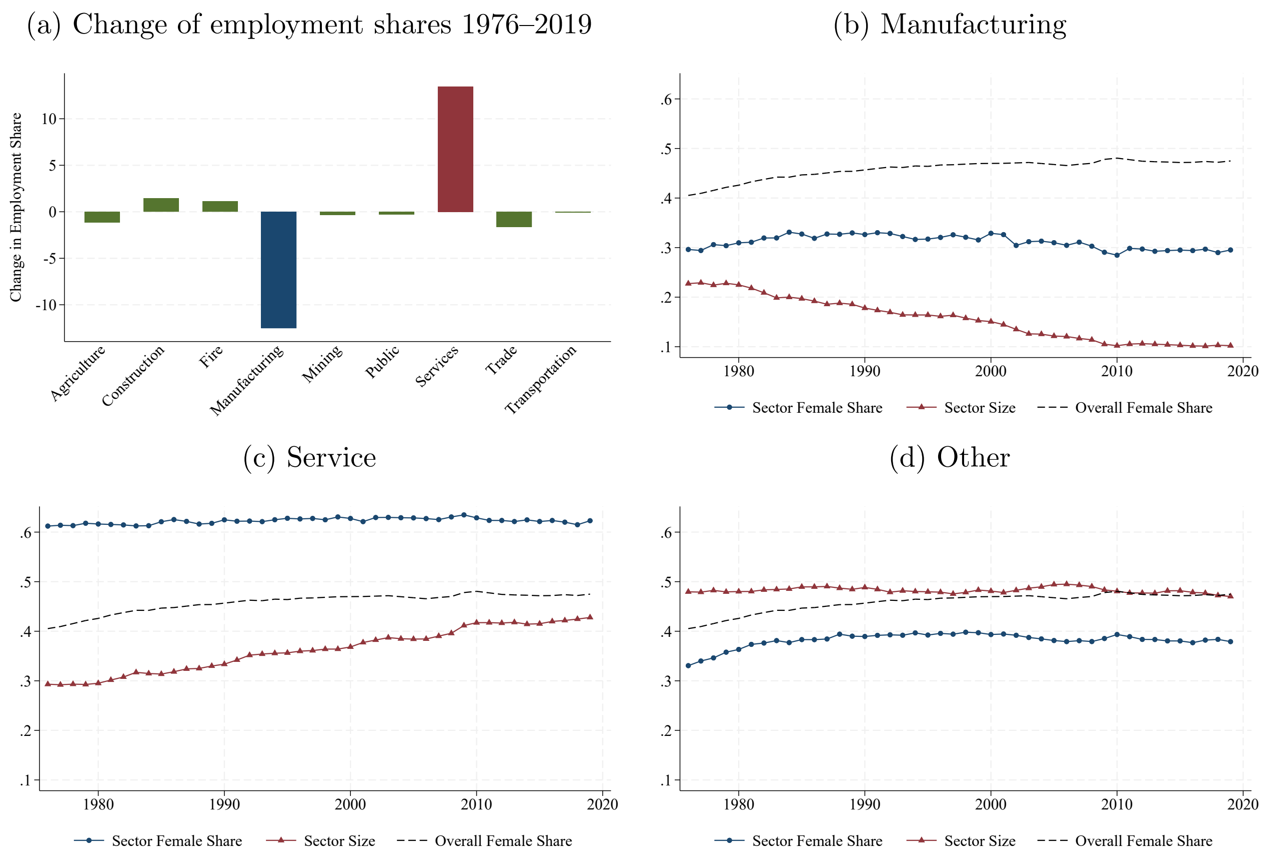
2.1.1 United States

For the United States, we rely on data from the March supplement of the Current Population Survey (CPS) obtained from IPUMS (Flood et al., 2021). The CPS data is the source for labor market reporting in the United States and offers a large representative sample of the U.S. population with rich demographic and labor market information. We rely on CPS microdata from 1976 to 2019. We abstain from any sample selection when constructing employment shares and use the harmonized IPUMS industry codes based on the 1990 Census Bureau industrial classification system.

Panel (a) in Figure 1 shows the changes in employment shares for ten disaggregated industries between 1976 and 2019. Whereas most industries saw hardly any change over time, two industries stand out: the employment share of manufacturing declined sharply while the employment share of services grew at least as dramatically.[5] Based on this observation, we group industries into three aggregated industry groups *manufacturing*, *services*, and *Other* – the latter sector combining all remaining industries that show little to no change in employment over

[5]Services contains business and repair services, personal services, entertainment and recreation services, and professional and related services (such as health services and educational services).

Figure 1: Industry employment shares and female employment shares in the U.S.



Notes: Panel (a) plots the change of employment shares for each industry. Panel (b) shows the share of females in total employment of the manufacturing sector (blue line), the employment share of the manufacturing sector (red line), and the female share in employment in the entire labor market (dashed black line). Panels (c) and (d) plot the same variables for the services and the other sector.

time. Table A-1 reports the classification of three-digit industries into manufacturing, services, and the Other sector.

The panels (b) to (d) of Figure 1 plot, for each of these three industries, the female employment share and the industry's share in overall employment. We also plot in each of these panels the female share of aggregate employment. Looking first at the aggregate female employment share, we observe a large increase from 40 percent in the mid 1970s to 47 percent in 2019. Second, we also see the secular trend of structural change with a shift from manufacturing to services. The service industry accounts for only 30 percent of the total employment in the late 1970s, but for 43 percent in 2019. At the same time, manufacturing declines from 23 percent of the total employment to only 10 percent. The employment share of the Other industry remained roughly constant.

The striking new fact that emerges in Figure 1 is the virtually constant gender shares within the manufacturing and service industry during this period. The female employment share in the service sector is around 62 percent. The female employment share in manufacturing is around 30 percent. Hence, we find that despite a massive increase in female employment, the within-sector gender employment share is almost unchanged over half a century. For the Other sector, we find that the female share roughly tracks the macroeconomic female share over time, although at a lower level.

2.1.2 France

The data on employment by industry and gender for France are obtained from INSEE.[6] The data are available for the period from 1989 to 2019 and are representative for the French labor market. We group detailed industries following the same classification as in the U.S. data. Figure 2(a) shows that, as in the United States, the structural change is narrowly concentrated in two industries, manufacturing and services, whereas other industries show roughly constant employment shares over time. Thus, we once again aggregate industries into the three industry groups: manufacturing, services, and Other.

Panels (b) to (d) of Figure 2 show the employment shares of each industry, female employment share in each industry and the aggregate female employment share. The time period is more than 10 years shorter than for the United States but we still see a substantial increase in the aggregate employment share of females from less than 45 percent in 1989 to 50 percent in 2019. Over the same time period, the manufacturing employment share contracts by around 10 percentage points and the services' share expands by the same amount. The Other industry's share remains virtually constant between 1989 and 2019.

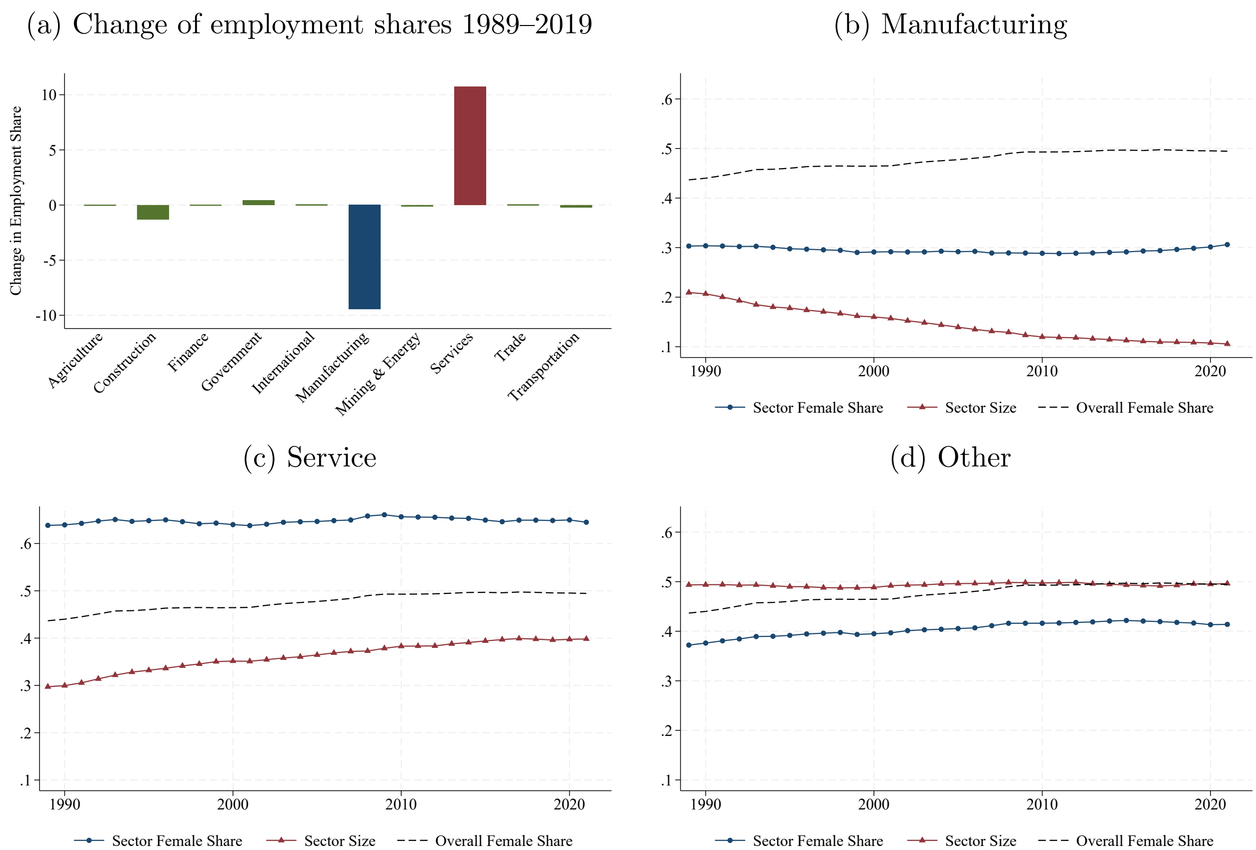
The French data also feature the same pattern we found in the US of strikingly constant female employment shares within service and manufacturing sectors over time. Moreover, the French female employment shares in manufacturing and services align closely with the corresponding shares in the United States with around 30 percent of female employment in manufacturing and 64 percent in services. The female share in the Other industry rises again in lockstep with the aggregate female employment share but at a lower level.

2.1.3 Germany

For Germany, we use data from the German Microcensus from 1973 to 2018. The German Microcensus is a 1 percent household survey of the German population and we rely on a scientific use file with a 70 percent subsample provided by the Research Data Center of the German Statistical Office (Statistisches Bundesamt, 2021). Participation in the survey is mandatory for

[6] https://www.insee.fr/en, Table "T102 : Emploi salarié en fin d'année en France (hors Mayotte) selon le secteur d'activité (A17 et A38) et le sexe."

Figure 2: Industry employment shares and female employment shares in France



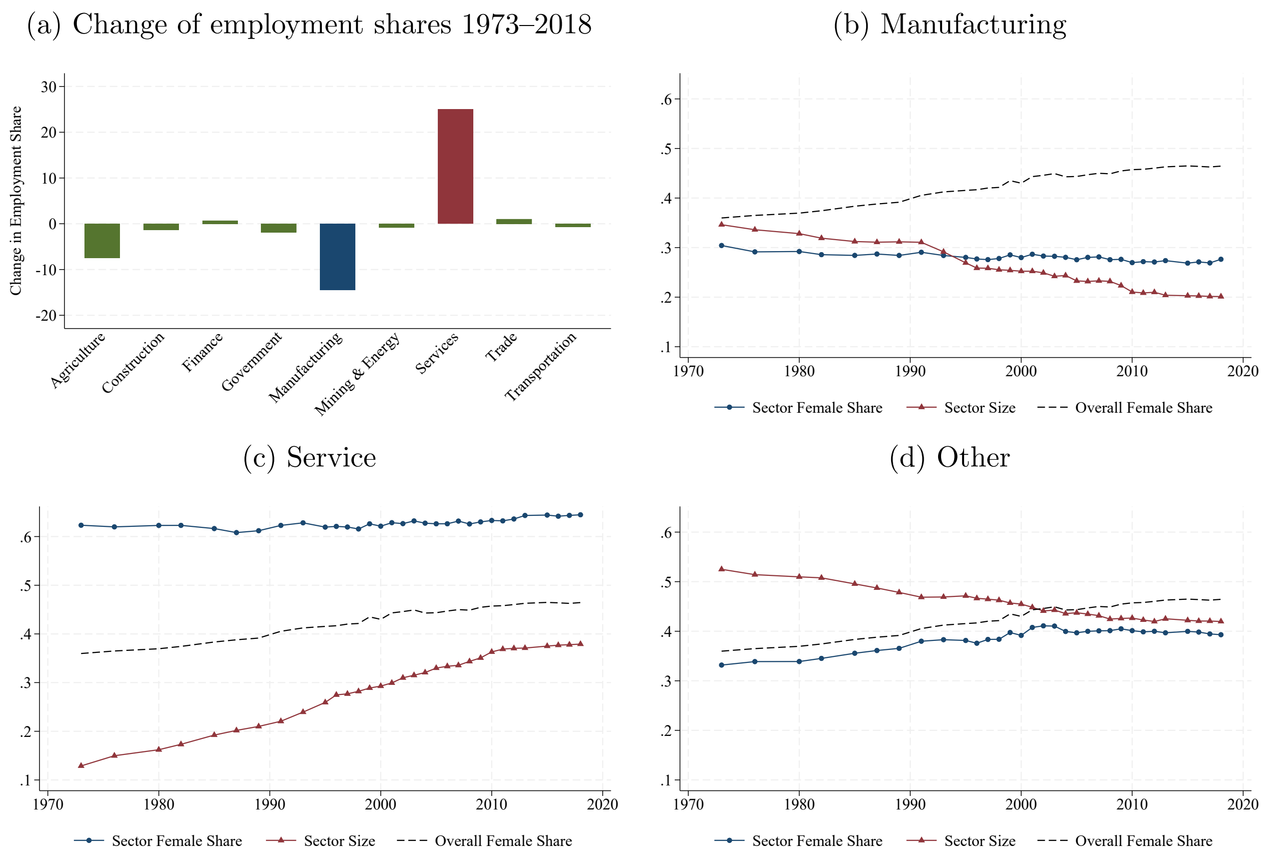
Notes: Panel (a) plots the change of employment shares for each industry. Panel (b) shows the share of females in total employment of the manufacturing sector (blue line), the employment share of the manufacturing sector (red line), and the female share in employment in the entire labor market (dashed black line). Panels (c) and (d) plot the same variables for the service and the other sector.

sampled households and reporting on the German labor market to international institutions is based on Microcensus data which follows the internationally comparable ILO classification for labor market states. For consistency over time, we restrict the sample to employed workers in West Germany but abstain otherwise from any sample selection. We group detailed industries in Germany to match the aggregation of detailed industries in the U.S. data.

Panel (a) in Figure 3 shows the changing employment shares of ten aggregated industries with very similar pattern to the United States. Most industries' employment shares hardly change over the forty five year sample period but manufacturing shows a strong decline and services an equally strong increase. The only other industry with a notable change in Germany is agriculture with decline of over 7 percent. Following the treatment of the U.S. data, we aggregate industries into the three broad industry groups: manufacturing, services, and Other.

In Panels (b) to (d) of Figure 3 we plot industry employment shares, females employment shares within industries, and the aggregate female employment share over time. We observe

Figure 3: Industry employment shares and female employment shares in Germany



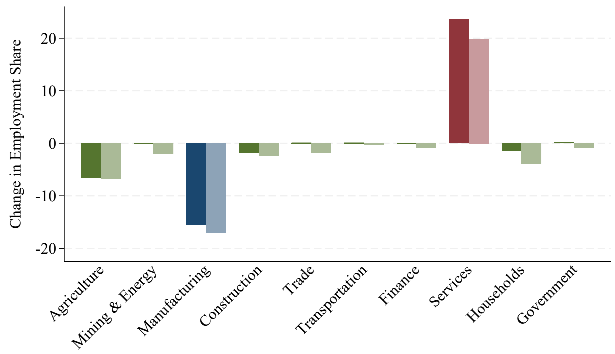
Notes: Panel (a) plots the change of employment shares for each industry. Panel (b) shows the share of females in total employment of the manufacturing sector (blue line), the employment share of the manufacturing sector (red line), and the female share in employment in the entire labor market (dashed black line). Panels (c) and (d) plot the same variables for the service and the other sector.

a strong structural transformation of the German labor market. In 1973, 35 percent of employment was in manufacturing whereas 40 years later only 20 percent of workers are employed in manufacturing. In contrast, the service industry expanded from 13 to 38 percent of employment. The Other industry declined by 10 percentage points over time mainly due to the decline of agriculture. At the same time, we observe a secular increase of the aggregate female employment share from 36 percent in 1973 to 46 percent in 2016.

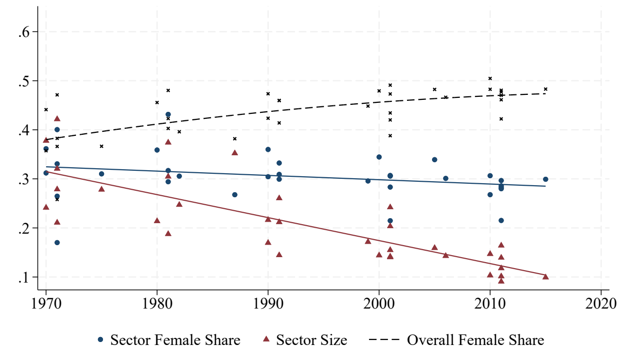
Strikingly, we once again find that despite these large changes the within-industry female employment shares in services and manufacturing remained virtually constant at 63 percent and 28 percent, respectively. The female employment shares in the manufacturing and services are not only constant over time but also at almost exactly the same level as in the United States and France. For the Other industry, we once again observe that its female employment share roughly tracked the aggregate female employment share over time although at a lower level.

Figure 4: Industry employment shares and female employment shares across countries

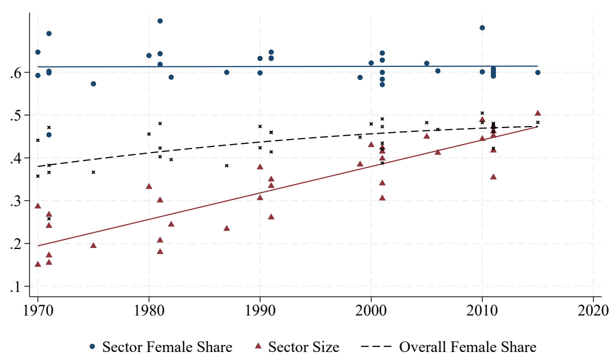
(a) Change of employment shares 1970–2015



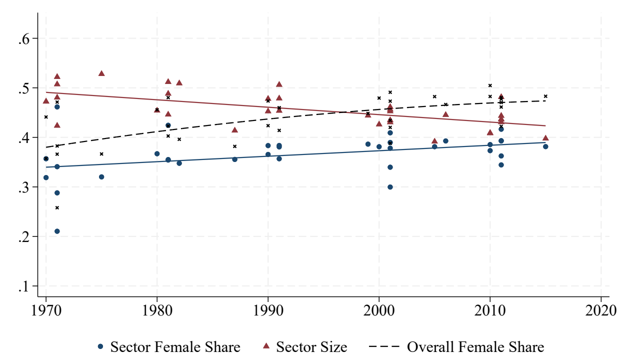
(b) Manufacturing



(c) Service



(d) Other



Notes: Panel (a) plots the change of employment shares for each industry, where the dark bars are for the sample of countries that report data for both 1970 and 2015 and the light bars are for the sample of all countries after imputing the missing data. Panel (b) shows the share of females in total employment of the manufacturing sector (blue line), the employment share of the manufacturing sector (red line), and the female share in employment in the entire labor market (dashed black line). Panels (c) and (d) plot the same variables for the service and the other sector.

2.1.4 Broad Sample of Developed Economies

To further assess the patterns of sectoral gender composition and structural change, we now consider a sample of countries that are among the 25 countries with highest GDP per capita in 1970. IPUMS (Minnesota Population Center, 2020) provide data for nine of these countries: Austria, Canada, Finland, France, Germany, Italy, Netherlands, United Kingdom, and United States. Countries provide data for different years in IPUMS and some also report only for part of the period from 1970 to 2015. For the industry classifcation, we rely on the harmonized industry definition in IPUMS international and aggregate detailed industries to mimic our aggregation approach for the U.S. data.

Figure 4 reports our usual statistics now based on cross-country-year averages (we show all country-year observations in panels (b)–(d)). The dark bars in Panel (a), indicate the change in sectoral employment shares for four countries that report data for both 1970 and 2015 that allows us to compute the change directly.[7] The light bars average across all countries in the sample after imputing the missing data. Specifically, we estimate country-industry-specific time trends for employment shares in each industry from the full sample and predict using these linear trends the employment shares in all possible waves. Based on these imputed employment shares, we proceed as before and compute employment shares for 1970 and 2015 to compute changes over time.

From the top left panel of Figure 4, we can see that the main employment changes across industries are concentrated in manufacturing and services, although there is also a decline of agriculture by around 5 percent. In the top right panel, we observe a strong increase in the aggregate female employment share by more than 10pp on average between 1970 and 2015. We once again find a constant share of females in manufacturing employment at 29%, while the manufacturing employment share declined from 30% to 10% over time. In the bottom left panel, we observe a constant female share of service employment at 61% across countries while the share of employment in services grows from 20% to almost 50%. Finally, the female employment share in the other sector tracks the aggregate female employment share. There is a decline in the employment share of the other sector that mainly stems from the decline of employment in agriculture.

2.1.5 Discussion

The evidence presented above highlights massive changes in industry composition and female employment over recent decades in the U.S. and other highly developed countries. All countries experienced a decline in manufacturing and an increase in services employment whereas the employment share of other industries remained largely unchanged (except for the decline in agriculture still taking place in several countries). We also find that despite a massive change in employment, the female employment shares in manufacturing and services are very similar across countries and they remained virtually constant over time.

We note that in this paper we consider relatively broadly defined industry sectors relevant for the study of structural change. Our finding of constant gender shares in manufacturing and services is quite unexpected given the well documented changes in gender composition over time in more finely defined sectors or occupations (see, e.g., Hsieh et al. (2019) and references therein). Given the focus of our paper, it is not necessary to develop an aggregation theory that yields constant gender shares at the level of broad sectors, which we take as given. Nevertheless, developing such a theory seems an interesting research question.

[7] We take for 1970 data from waves taken in 1968, 1970, 1971, or 1975 and average if there is data for one country in more than one wave. For 2015, we proceed accordingly for waves 2010, 2011, and 2015.

It is also important to note that the patterns we uncover are characteristic of highly advanced economies. We did not engage in a systematic study of economies at earlier stages of development but a casual exploration did not reveal systematically constant gender shares in manufacturing and services among those countries.

2.2 Changing Female Employment: A Driving Force of Structural Change?

The descriptive evidence shows the tight correlation between structural change and female employment. The constant manufacturing and services gender shares in combination with rising aggregate female employment suggest that in theory rising female employment may itself induce structural change (Rybczynski theorem). Before conducting a structural quantitative theory evaluation of the role of this mechanism, we present empirical evidence suggesting its potential importance. To do so, we consider several instrumental variable regressions exploiting first cross-state variations within the United States and next variations among the broad sample of developed economies that we used in the descriptive analysis.

2.2.1 State-Level Evidence from the United States

To assess the impact of an exogenous change in female employment on the industrial structure, we consider a regression with annual observations on U.S. states

$$y_{it} = \alpha_0 + \alpha_1 x_{it} + \varepsilon_{it}, \tag{1}$$

where y_{it} is the manufacturing or services employment share in state i at time t and x_{it} is the aggregate female employment share. To identify an exogenous (to structural change) variation in female employment, we consider a number of instruments for x_{it}, including state-level variations in the timing of the introduction of the unilateral divorce laws, marriage patterns, generosity of Earned Income Tax Credit (EITC) programs, as well as differences in income tax systems. None of these instruments is entirely perfect, but, taken together, the results based on all of them paint a fairly consistent picture.

Unilateral Divorce Laws Differences in marital status are associated with large differences in female employment. Ample research has established the impact of the marriage market and divorce legislation on women's labor supply (Gray, 1998; Chiappori, Fortin and Lacroix, 2002; Fernández and Wong, 2014). There is large variation in marriage and divorce rates across US states. Extensive sociological research highlights that these differences are largely induced by religion, norms, attitudes, and differences in divorce laws. The first instrument we use is the

Table 1: IV Estimates of the Impact of Female Employment on Industrial Structure

	Services Share				Manufacturing Share			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Female Share	3.107***	2.875***	2.743***	2.737***	-3.459***	-1.747***	-2.123***	-2.188***
	(0.207)	(0.098)	(0.093)	(0.091)	(0.296)	(0.114)	(0.117)	(0.115)
Instrument	UDL	Marriage	E4	E1–E4	UDL	Marriage	E4	E1–E4
Observations	2040	2040	2040	2040	2040	2040	2040	2040
Weak Id. F	95.93	1088.04	1164.34	312.09	95.93	1088.04	1164.34	312.09

* p<0.1, ** p<0.05, *** p<0.01

Notes: This table reports the instrumental variable estimates where the aggregate state-level female employment share is instrumented by unilateral divorce laws, marriage rates, or EITC schedules.

variations in unilateral divorce regulations across states over time. The adoption of unilateral divorce laws (UDL) across the United States occurred in a staggered manner over several decades (see Appendix I.2). Our identifying assumption is that differences in the timing of the introduction of unilateral divorce laws are not induced by the cross-state differences in the industrial structure. The idea of this instrument builds on the literature that examines how unilateral divorce laws affect divorce (Friedberg, 1998; Wolfers, 2006) and female labor supply (Gray, 1998; Stevenson, 2008; Gruber, 2004; Voena, 2015).

Table 1 reports the instrumental variable estimates. In Column (1), we use a dummy indicating the presence of unilateral divorce laws and the number of years since the introduction of the unilateral divorce laws as the instrumental variables for the state-level female employment share. In Column (2), we use the marriage rate among working-age women as instrument for the state-level female employment share. We find that as the female employment share increases by 1%, the service employment share increases by 2.9% to 3.1% (columns 1–2) and the manufacturing employment share decreases by 1.7% to 3.4% (columns 5–6), suggesting that increasing female employment is a driving force of structural change. The last row of Table 1 reports the F statistics for weak identification (Cragg and Donald, 1993; Kleibergen and Paap, 2006) and confirms a robust rejection of the null hypothesis of weak instruments. We also report the estimates directly using the divorce rate among working-age women (between 16 and 65 years old) as the instrument in Appendix Table A-3 and find similar results.

Earned Income Tax Credit It is well established that differences in the EITC programs affect the labor supply, particularly so for female workers (Eissa and Liebman, 1996; Meyer and Rosenbaum, 2001; Bastian, 2020). Hotz and Scholz (2003) and Nichols and Rothstein (2016) provide detailed descriptions of the EITC program and review of the main empirical findings on its effects. Under the assumption that the EITC program differences do not directly impact the industrial structure, they are a valid instrument for the aggregate female employment.

We summarize an EITC schedule by four parameters (E_1, E_2, E_3, E_4), such that income interval $[0, E_1]$ is the phase-in part, $[E_1, E_2]$ the flat phase, $[E_2, E_3]$ the phase-out part of the schedule, and E_4 is the amount of maximum benefit. Thus an EITC schedule as a function of income can be represented by

$$\text{EITC}\,(Y) = \frac{E_4}{E_1} Y \cdot \mathbb{1}_{\{0 \le Y \le E_1\}} + E_4 \cdot \mathbb{1}_{\{E_1 \le Y \le E_2\}} + \left[E_4 - \frac{E_4}{E_3 - E_2} (Y - E_2) \right] \cdot \mathbb{1}_{\{E_2 \le Y \le E_3\}},$$

where $\mathbb{1}$ denotes an indicator function and Y denotes family labor income. The set of parameters (E_1, E_2, E_3, E_4) varies across states and over time. See Appendix I.3 for more details.

Columns (3)–(4) and (7)–(8) in Table 1 report the results using EITC as instrumental variable. We use two different sets of IVs, one only with E_4, which both varies the most and affects labor supply the most, and the other with all four parameters $E1$ to $E4$. We find that as the female employment share increases by 1%, the service share increases by 2.7% (columns 3–4) and the manufacturing share decreases by 2.1% to 2.2% (columns 7–8). The point estimates are quite similar to the estimates using divorce legislations and marriage rates as instruments.

Appendix I.4 shows that the results remain quantitatively similar when we use features of the income tax system, i.e., the tax level and the tax progressivity, as the instruments.

Discussion. What would the theory imply? Consider, for simplicity, our motivating framework with only two sectors, manufacturing and services. Although the employment in the Other sector is endogenously determined, we have seen that it remains virtually constant as the share of the aggregate employment in the data. Thus, a theoretical framework featuring only reallocation of labor between manufacturing and services, is a somewhat rough but meaningful guide for interpreting the magnitudes in the data. Given the constant gender shares within manufacturing m and services s, the market clearing condition requires that

$$N_m f_m + N_s f_s = L_f,$$

where N_m and N_s are the employment of the manufacturing and service sectors, f_m and f_s are the female employment share in these two sectors, and L_f is the overall female employment. Dividing both sides by total employment, we have

$$n_m f_m + n_s f_s = \ell_f,$$

where n_m and n_s are the manufacturing share and service share, and ℓ_f is the overall female employment share. Substituting $n_m = 1 - n_s$, yields

$$\frac{\mathrm{d}n_s}{\mathrm{d}\ell_f} = \frac{1}{f_s - f_m}.$$

Empirically, we have $f_m \approx 0.30$ and $f_s \approx 0.62$, which implies that

$$\frac{\mathrm{d}n_s}{\mathrm{d}\ell_f} = \frac{1}{0.62 - 0.30} = 3.13.$$

Our IV estimates in the data turn out to be very similar. Extrapolating these estimates illustrates their economic significance: a 8pp increase in female employment will be associated with a 25pp increase of the service sector. However, we have to be careful with such an extrapolation of the regression results as they abstract from general equilibrium effects and changes in the other sector that also increased its female employment share. To quantify the contribution of female employment to structural change, we will therefore rely on our model in Section 3 that takes these effects into account.

Level vs. Share Our simple organizing framework suggests an even more striking implication that with constant gender employment shares in manufacturing and services, an increase in aggregate female employment will lead to a decline in manufacturing employment not only as a share of the economy, but in the absolute level. To see this, note that

$$N_m f_m + N_s f_s = L_f, \quad N_m(1 - f_m) + N_s(1 - f_s) = L_m.$$

Rearranging the second equation

$$N_s = \frac{L_m - N_m(1 - f_m)}{1 - f_s}$$

and plugging it into the first equation yields

$$N_m f_m + \frac{L_m - N_m(1 - f_m)}{1 - f_s} f_s = L_f.$$

After collecting terms, we get that conditional on constant male employment (i.e., $\mathrm{d}L_m = 0$)

$$\frac{\mathrm{d}N_m}{\mathrm{d}L_f} = \frac{1 - f_s}{f_m - f_s} < 0$$

because in the data $0.30 \approx f_m < f_s \approx 0.62$.

Table 2: IV Estimates of the Impact of Female Employment on Industrial Structure (Levels)

	Services Employment				Manufacturing Employment			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Female	1.810***	1.841***	1.745***	1.728***	-1.268***	-0.790***	-0.982***	-1.013***
	(0.174)	(0.106)	(0.074)	(0.072)	(0.228)	(0.122)	(0.092)	(0.090)
Male	-0.855***	-0.881***	-0.799***	-0.784***	1.361***	0.950***	1.116***	1.142***
	(0.150)	(0.091)	(0.063)	(0.062)	(0.196)	(0.105)	(0.079)	(0.078)
Instrument	UDL	Marriage	E4	E1–E4	UDL	Marriage	E4	E1–E4
Observations	2040	2040	2040	2040	2040	2040	2040	2040
Weak Id. F	33.66	198.85	418.02	110.31	33.66	198.85	418.02	110.31

* $p<0.1$, ** $p<0.05$, *** $p<0.01$

Notes: This table reports the instrumental variable estimates where the female employment is instrumented by the unilateral divorce laws, marriage rates, or EITC schedules.

We contrast this theoretical prediction with the data by examining the impact of aggregate female employment changes on the absolute sector sizes using the following regression specification:

$$y_{it} = \alpha_0 + \alpha_1 x_{it} + \alpha_2 z_{it} + \varepsilon_{it}, \tag{2}$$

where y_{it} is the manufacturing or services employment level, x_{it} is the level of female employment, and z_{it} is the level of male employment level in state i at time t. The latter regressor controls for the male employment, i.e., $\mathrm{d}L_m = 0$, as required by the derivation above. We instrument aggregate female employment using the same instruments as above. Table 2 reports results using divorce laws, marriage rates, and EITC generosity as instruments. Appendix Table A-4 report similar results using the divorce rates and income tax system parameters as instruments.

The results are consistent with the theoretical prediction that with constant gender shares in manufacturing and services, increasing aggregate female employment leads to a decline of the male-intensive sector (manufacturing) and an increase of the female-intensive sector (services). The estimates are also quantitatively consistent with the prediction of the basic theory. For example, the theory implies that for $f_s = 0.62$ and $f_m = 0.30$ and conditional on constant male employment (i.e., $\mathrm{d}L_m = 0$),

$$\frac{\mathrm{d}N_s}{\mathrm{d}L_f} = \frac{1}{f_s - \frac{1-f_s}{1-f_m} f_m} = 2.1,$$

which is close to the corresponding estimates in the data of around 1.8. As in the case of shares,

Table 3: Cross-Country IV Estimates of the Impact of Aggregate Female Employment on Industrial Structure

	Employment Share		Employment Level	
	Services	Manufacturing	Services	Manufacturing
	(1)	(2)	(3)	(4)
Divorce IV	2.52	-1.54	2.39	-1.07
	(0.34)	(0.32)	(0.18)	(0.13)
Attitudes IV	1.78	-1.44	4.12	-1.62
	(0.60)	(0.53)	(1.88)	(0.87)
no. observations	37/32	37/32	37/32	37/32

Notes: Standard errors in parenthesis.

these estimates have to be interpreted carefully as they abstract from several effects that our structural model below takes into account.

2.2.2 Cross-Country Evidence

The preceding analyses based on U.S. states suggest that an exogenous increase in aggregate female employment is associated with a decline in the share and the level of employment in manufacturing and an increase in the share and the level of employment in services. We now assess whether a similar relationship holds in our sample of advanced economies.

As in the case of U.S. states, we need to construct instruments for changes in female employment. We propose two such instruments. First, we use attitudes toward female employment from the 2002 *International Social Survey: Family and Changing Gender Roles* (ISSP 2002). The ISSP is a long-running social survey program that asks respondents across countries about a variety of topics. It includes specific modules, such as on the family and changing gender roles, which we use to construct our instrument (Fernández et al., 2004). Specifically, we use the response to the question, "To what extent do you agree or disagree with being a housewife is just as fulfilling as working for pay?" Respondents can choose from five answers ranging from strongly agree to strongly disagree, or they can answer that they cannot choose. We use the average response to this question for each country as our first instrument. Second, as an alternative instrument, we use the divorce rates as measure of divorce legislation and practice as well as social norms in each country (Chakraborty et al., 2015). We use the same sample as in the analysis of employment shares and determine the divorce rate for each country-year observation using information on marital status in IPUMS.

Table 3 reports the results for the two IV regressions for the four outcome variables of interest − manufacturing and service employment shares and levels. The results are similar to those based on U.S. states. The manufacturing employment share and level decrease while the services employment share and level increase with an increase of female employment. Hence, the cross-country evidence corroborates the cross-state evidence from the U.S. on the impact of increasing female employment on structural change.

3 Quantitative Model

In this section, we propose a quantitative model of structural change induced by differential sectoral productivity growth, income effects due to non-homothetic preferences, and rising female employment over time. The first two forces are standard in the literature while the third one is new. The model takes as given the observed sectoral productivity growth and changes in overall female employment. It is not material to our analysis why aggregate female employment increased over time, although a large literature (see Olivetti and Petrongolo, 2016, for a survey) provides a plethora of potential explanations. Instead, our objective is to quantify the equilibrium contribution of rising female employment to the observed structural change.

3.1 Setup

Preferences. Consumers' preference over the sectoral goods m (manufacturing), s (service), and o (Other) exhibit the following nested CES structure:

$$Y=\left[\beta y^{\frac{\rho-1}{\rho}}+(1-\beta)\left(y_o-\bar{y}_o\right)^{\frac{\rho-1}{\rho}}\right]^{\frac{\rho}{\rho-1}};\quad y=\left[\alpha\left(y_m-\bar{y}_m\right)^{\frac{\varepsilon-1}{\varepsilon}}+(1-\alpha)\left(y_s-\bar{y}_s\right)^{\frac{\varepsilon-1}{\varepsilon}}\right]^{\frac{\varepsilon}{\varepsilon-1}},$$

where y is a composite of manufacturing goods and services. Preferences are non-homothetic, as characterized by parameters $\bar{y}_m$, $\bar{y}_s$, and $\bar{y}_o$. We denote the price of each sectoral good by p_m, p_s, and p_o, respectively. We define the price index by

$$P\equiv\left[\beta^{\rho}p^{1-\rho}+(1-\beta)^{\rho}p_o^{1-\rho}\right]^{\frac{1}{1-\rho}};\quad p\equiv\left[\alpha^{\varepsilon}p_m^{1-\varepsilon}+(1-\alpha)^{\varepsilon}p_s^{1-\varepsilon}\right]^{\frac{1}{1-\varepsilon}},$$

where p defines the price index of the manufacturing-service composite. Consumers optimization problem implies the following demand system:

$$p_m=\alpha p\left(\frac{y_m-\bar{y}_m}{y}\right)^{-\frac{1}{\varepsilon}};\quad p_s=(1-\alpha)\,p\left(\frac{y_s-\bar{y}_s}{y}\right)^{-\frac{1}{\varepsilon}},$$

and

$$p = \beta P \left(\frac{y}{Y}\right)^{-\frac{1}{\rho}}; \quad p_o = (1-\beta) P \left(\frac{y_o - \bar{y}_o}{Y}\right)^{-\frac{1}{\rho}}.$$

We normalize the price index to $P = 1$.

Technology. Each sector has a specific production function that takes male and female labor services as inputs. Denote the labor inputs by N_ℓ and N_g for female and male workers, respectively (ℓ for ladies and g for gentlemen). We abstract from capital for simplicity.[8] The empirical evidence in Section 2 revealed constant gender ratios in the manufacturing and service sectors over time and across countries. We therefore assume that production functions are Leontief in these two sectors given by

$$F_j\left(N_{\ell,j}, N_{g,j}\right) = A_j \min\left\{N_{\ell,j}, B_j N_{g,j}\right\},$$

where A_j is TFP and B_j captures the gender input intensity in sector $j \in \{m, s\}$.[9] The production function in the Other sector takes a similar form, but the gender intensity parameter is a function of the economy-wide female employment share $B_o\left(L_\ell/L\right)$, which is parameterized as a polynomial. Within each sector, there is a representative firm. Firms take wages as given and solve the following cost minimization problem

$$\begin{aligned} \min_{N_{\ell,j}, N_{g,j}} \quad & w_\ell N_{\ell,j} + w_g N_{g,j} \\ \text{s.t.} \quad & F_j\left(N_{\ell,j}, N_{g,j}\right) \geq y_j, \end{aligned}$$

where w_ℓ and w_g are the wages of each gender. Note that workers are assumed to be freely mobile across sectors so that wages are equalized across sectors

$$w_{\ell,m} = w_{\ell,s} = w_{\ell,o} := w_\ell, \; w_{g,m} = w_{g,s} = w_{g,o} := w_g.$$

Equilibrium. The definition of a competitive equilibrium is standard. It is an allocation of workers across sectors $\{N_{\ell,m}, N_{\ell,s}, N_{\ell,o}\}$ and $\{N_{g,m}, N_{g,s}, N_{g,o}\}$ such that the representative firms take prices as given and maximize profits. Prices are such that the labor market clears for each gender $\sum_j N_{\ell,j} = L_\ell$, $\sum_j N_{g,j} = L_g$ and there is goods market clearing $y_j = F_j\left(N_{\ell,j}, N_{g,j}\right)$ for each sectoral good $j \in \{m, s, o\}$. There is free entry so that the zero-profit condition holds

[8] Introducing a frictionless capital market would result in the same reduced form production functions for labor inputs.

[9] As is common practice in economics, the observed input intensity is attributed to some form of the production function. A prominent example is that the observed constancy of the factor share of labor in national income is typically formulated via a Cobb-Douglas production function in capital and labor. Similarly, here, the observed constancy of the gender employment share is consistent with a Leontief production.

in each sector

$$p_j F_j\left(N_{\ell,j}, N_{g,j}\right) - w_\ell N_{\ell,j} - w_g N_{g,j} = 0, \quad \forall j \in \{m, s, o\}.$$

3.2 Calibration

Parameters to be calibrated. There are 7 preference parameters to be calibrated: α, the weight parameter for manufacturing in the manufacturing-service composite production; ε, the elasticity of substitution between manufacturing and services; β, the weight parameter for manufacturing-service composite relative to other sector good; ρ, the elasticity of substitution between manufacturing-service composite and other sector good; $\bar{y}_m$, $\bar{y}_s$, and $\bar{y}_o$, the non-homotheticity parameters associated with the manufacturing goods, service goods, and other goods, respectively.

The technology parameters to be calibrated are the following. First, B_m and B_s, the gender intensities of the production functions that determine gender employment shares in manufacturing and service, respectively. Second, the polynomial $B_o\left(L_\ell/L\right)$ for the other sector, which is parameterized as a quadratic form. In addition, we have 3 TFP series to calibrate: $\{A_m^t, A_s^t, A_o^t\}$.

Lastly, the rise in the number of female workers in the labor market, $\{L_\ell^t\}$.

Calibration strategy. The model is calibrated to the US data. The rise in female employment, $\{L_\ell^t\}$ is taken directly taken from the data.

The constant employment shares of male and female workers in manufacturing and services in the data pin down B_m and B_s. To match the observed gender share in manufacturing and services, 0.30 and 0.62, respectively, we calibrate B_m to 0.4286 ($= 0.30/0.70$) and B_s to 1.6316 ($= 0.62/0.38$). We then estimate $B_o\left(L_\ell/L\right)$ by fitting a polynomial of B_o^t on L_ℓ^t/L^t. The TFP path A_j^t in each sector is inverted directly from sectoral value added and employment data as

$$A_j^t = \frac{Y_j^t}{\min\left\{N_{\ell,j}^t, B_j N_{g,j}^t\right\}} = \frac{Y_j^t}{N_{\ell,j}^t},$$

where Y_j^t is the value-added of sector j at time t and $N_{\ell,j}^t$ is the female employment of sector j at time t. The Leontief production function leads to such tractability. Since the model abstracts away from capital, we account for the labor share in the free entry condition of each sector in the calibration.[10]

The remaining preference parameters are calibrated internally. The model is solved as a series of static equilibria with exogenous sequences of sectoral productivity and economy-wide female labor supply. We estimate these 7 parameters by minimizing the distance of the model and data

[10]We adapt the revenue function from $p_j F_j$ to $\lambda_j p_j F_j$, where λ_j is the labor share in sector j.

Table 4: Internal Calibration

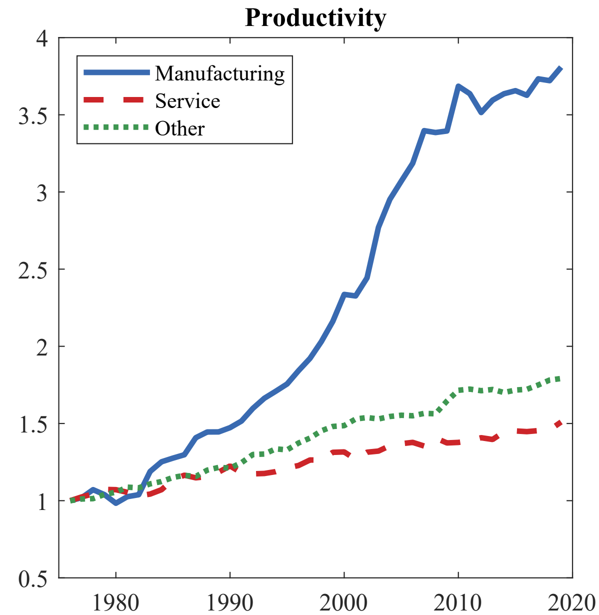
Meaning	Symbol	Value
Elasticity of substitution between m and s	ε	1.10
Elasticity of substitution between m/s and o	ρ	1.65
Weight parameter on m vs. s	α	0.14
Weight parameter on m/s vs. o	β	0.51
Nonhomotheticity parameter for m	$\bar{y}_m$	0.47
Nonhomotheticity parameter for s	$\bar{y}_s$	−0.58
Nonhomotheticity parameter for o	$\bar{y}_o$	0.35

Notes: Internally calibrated preference parameters and their calibrated values in the model.

counterpart of the following moments: (1) the time paths of the sector sizes of manufacturing and services; (2) the time paths of the relative price of the service goods to manufacturing goods and the other goods to manufacturing goods. We obtain annual data on chain-weighted quantity indices and chain-weighted price indices for each industry from the Bureau of Economic Analysis (BEA) and aggregate them into the quantities and prices for the three broad sectors using the so called cyclical expansion procedure as is done in Herrendorf et al. (2013). See Appendix III for the details of the aggregation procedure.

Table 4 reports the values of internally calibrated parameters. Figure 5 plots the calibrated paths of sectoral productivity over time. The manufacturing sector has experienced the fastest productivity growth, and the service sector the slowest. The productivity growth in the other sector lies in between.

Figure 5: Calibrated Sectoral Productivity Growth



Notes: This figure plots the calibrated sectoral productivity processes.

3.3 Model Fit

Henceforth, we refer to sector j's female share as the fraction of its employees who are female:

$$\text{female share}_j = \frac{N_{\ell,j}}{N_{\ell,j} + N_{g,j}},$$

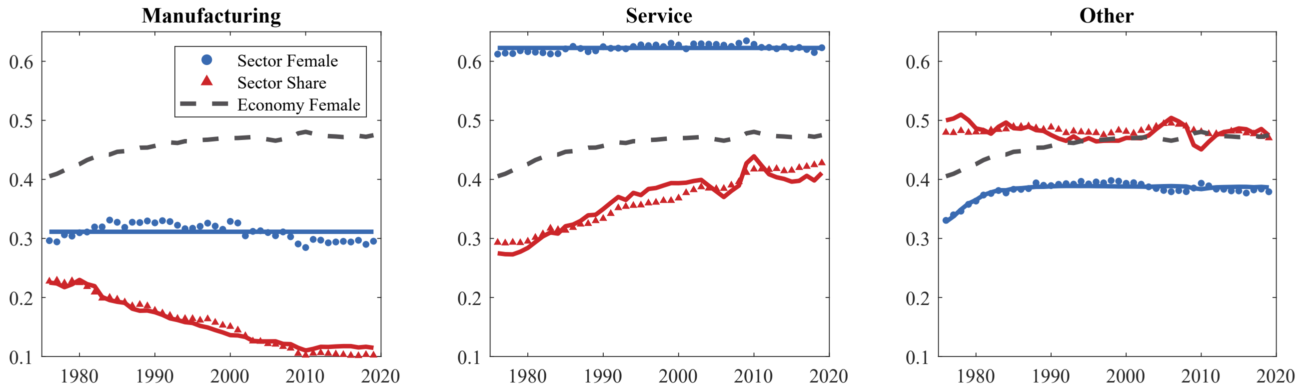
and to sector j's size as its share in the economy-wide employment:

$$\text{sector size}_j = \frac{N_{\ell,j} + N_{g,j}}{\sum_{j \in \{m,s,o\}} (N_{\ell,j} + N_{g,j})}.$$

Figure 6 shows the model fit for the key objects of interest for the manufacturing, services, and other sector. The blue dots plot the employment share of female workers in each sector in the data, and the blue lines are the model counterpart. The red dots plot the sector employment share in the data, and the red lines are the model counterpart. The black dashed line in each panel tracks the economy-wide female employment share in the data, which evolves in exactly the same way in the model. As all the lines are almost exactly on top of the corresponding dots, the model is able to replicate the structural shift from manufacturing to services. The constant gender employment shares in manufacturing and services, and the parallel trend relative to the economy-wide gender share in the other sector are matched by construction.

In addition, Figure 7a shows that the model reproduces the movements in the relative prices of the sectoral goods. As before, dots are data and lines are model counterparts. Figure 7b

Figure 6: Model Fit—Sector Size and Gender Share



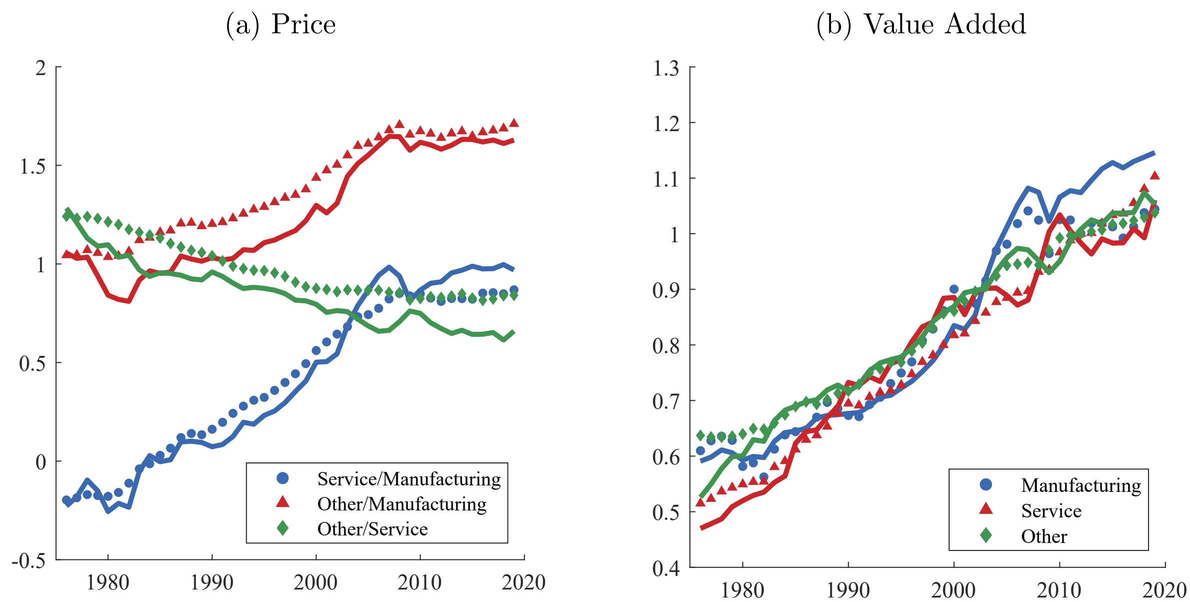
Notes: This figure plots the employment size of each sector, female employment share of each sector, and female employment share in the economy, both in the data (circles and triangles) and in the model (solid lines).

plots the paths of value-added of each sector in the data and in the model.

Finally, the model is consistent with a significant reduction in the difference between the average wages of male and female workers, the gender gap, as we show in Appendix Figure A-3. While the rise in female labor supply tends to push their relative wages down, this is more than offset by the sharp rise in the price of services relative to the other two sectors. As the production of services is intensive in female labor, the relative wage of female workers increases.

In summary, the model is able to reproduce the key facts of structural change over the past 50 years, including the time paths of sectoral employment, gender shares, prices, value added, and the gender gap in wages. This allows us to use the model a quantitative laboratory to study the quantitative importance of different drivers of structural change.

Figure 7: Model Fit—Price and Value Added



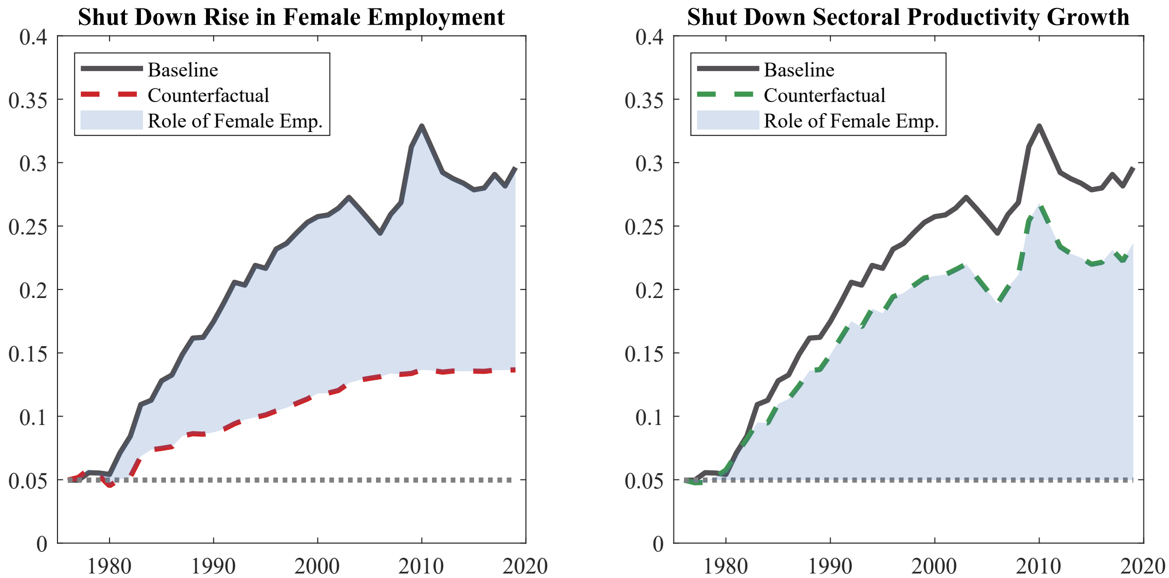
Notes: The left panel plots log price ratio of sectoral goods. The right panel plots value added of sectoral goods. Dots are data points and solid lines are model counterparts.

3.4 Counterfactual Experiments

Three forces potentially lead to structural transformation of employment reallocation from manufacturing to services: (1) an income effect embedded in the non-homothetic preference due to productivity growth; (2) differential productivity growth across sectors; (3) a rise in the number of female workers in the labor market. All three forces are essential in accounting for the observed patterns of structural change in the data. With the rise in the number of female workers only, one can obtain structural employment reallocation from manufacturing to services, but the relative price of the services to manufacturing good would decline in the model while it increases in the data. In contrast, in the absence of the rise in the number of female workers, one can still get some structural employment reallocation from manufacturing to services, as long as there are differential technological growth and/or an income effect. This has been well-known in the structural change literature. But without the rise of female employment, structural change must happen by reallocating women from the other sector, implying a decreasing female employment in the other sector. This prediction of the theory is counterfactual given the empirical fact that the female employment increases in the other sector. This observation leads to the conclusion that rising female employment is a necessary condition for generating structural change.

To measure the contribution of the rise in female employment to structural change we conduct two counterfactual experiments. As a metric for measuring "structural transformation" we use the difference in the services employment share and the manufacturing employment share. That

Figure 8: Counterfactual Analysis



Notes: This figure plots the magnitude of the employment reallocation from manufacturing to service in the counterfactual economies.

is, we quantify structural change by ΔQ, where Q is defined as

$$Q := \text{sector size}_{\text{services}} - \text{sector size}_{\text{manufacturing}}.$$

In the data, Q goes from 6.6pp in 1976 to 32.6pp in 2019, i.e., a 26pp of observed structural change as measured by ΔQ_{data}. The baseline model accounts for 95% of the structural change in the data (i.e., $\Delta Q_{\text{baseline}} = 24.7$ pp).

In the first experiment, we shut down the increase of female employment and compare the resulting counterfactual economy with the baseline. Specifically, we consider a counterfactual economy where the economy-wide female employment remains fixed at its level in 1976, i.e., $L_\ell^t = L_\ell^{1976}$ for all t, while keeping the paths of sectoral productivity growth as estimated. The path of structural transformation in this counterfactual economy is plotted as the red dashed line in the left panel of Figure 8. In this counterfactual economy, there is a $\Delta Q_{\text{no female}} =$ 8.7 ppt structural change, which suggests that the rise in female employment accounts for 65% (= $(\Delta Q_{\text{baseline}} - \Delta Q_{\text{no female}})/\Delta Q_{\text{baseline}}$) of the observed structural change. Appendix Figure A-4 plots the details of the employment allocation in this counterfactual economy. The counterfactual highlights the essential role of female labor supply for the growth of the service sector. The service sector is more female intensive than the rest of the economy and it requires the inflow of additional females to grow. This dependence on female workers makes female labor supply a necessary condition for the large observed reallocation of employment from male-intensive manufacturing to the female-intensive service sector.

In the second counterfactual experiment, we shutdown the differential productivity growth across sectors by assuming all three sectors have zero productivity growth (note that this also eliminates most of the income effects).[11] Removing the exogenous part of the income effect and the differential productivity growth leaves only the rise of female employment as exogenous cause of structural change in the model. We show the consequences on structural change from this counterfactual as the green dashed line in the right panel of Figure 8. Using our measure of structural change, we find that increasing female labor supply alone accounts for 18.7pp, or 76% of structural change in the data.

Both counterfactuals reveal the key role played by rising female employment on the reallocation of employment from manufacturing to services. The measured contribution of female employment to structural change varies from 65% to 76% in the two counterfactuals because the three drivers of structural change interact and the decomposition is therefore not additive. Yet, we can conclude from the two counterfactuals that the increase in female employment accounts for at least two-thirds of structural change in the data.

4 Conclusions

Labor markets underwent large changes during the last five decades. Industrialized countries observed massive shifts from a male-dominated labor market with a large share of employment in manufacturing to a service-dominated economy with aggregate female employment almost on par with men. Against this background, we find a strikingly constant gender ratios in the manufacturing and service sectors that underwent the largest shifts in employment. We document these facts for the United States and other advanced economies. These empirical findings guide our extension of the standard model of structural change to include a complementarity between male and female workers in sectoral production. The model implies that rising female employment can itself be an important cause rather than a consequence of structural change. Rising aggregate female employment in the model leads to rising employment share of services as sectoral gender balance constraints prevent the manufacturing sector from absorbing women who enter the labor market. On the flip side, the model implies that rising aggregate female employment is indeed necessary to support a large employment shift from male-intensive manufacturing to female-intensive services. We provide evidence based on instrumental variable regressions supporting the presence of this mechanism in the data. Our quantitative theory evaluation suggests that the increase in aggregate female employment accounts for at least two-thirds of the structural transformation that happened in the U.S. during the past five decades.

[11] The changing sectoral composition still leads to some aggregate productivity and income changes.

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APPENDICES FOR ONLINE PUBLICATION

I Empirical Appendix

I.1 Industry Classification

Table A-1: Classification of Industries

Sector	3-Digit Industry Code (1990 basis)
Manufacturing	100–392
Services	721–893, 641
Other	All the other industries

Table A-1 reports the classification of three-digit industries (based on the 1990 Census Bureau industrial classification system) into manufacturing, services, and the other sector. For consistency with Germany and France, we take industry 641, eating and drinking places, from retail trade to the services sector. Leaving it in the Other sector does not change the result but only shifts the share of the services employment to a slightly lower level.

I.2 Unilateral Divorce Law Reforms

Before the 1960s, most states mandated that a divorce could only be granted under mutual consent, where both spouses agreed to the dissolution, or on grounds of fault, such as adultery or domestic violence. Between the late 1960s and 1990s, the so-called "unilateral divorce revolution" took place, and the number of states that adopted unilateral divorce laws increased rapidly. Under the unilateral divorce regime, spouses are allowed to divorce without the consent of the other party. Table A-2 reports the year when unilateral divorce laws came into effect across states.

I.3 Earned Income Tax Credit

Initially set up in 1975, the Earned Income Tax Credit (EITC) was designed to boost the income of working families. Over the years, it has expanded significantly, particularly in 1986, 1993, and 2009, evolving into one of the most substantial income support programs in the United States. To qualify for the EITC, individuals must have a dependent child, earn a positive income, and

Table A-2: Timing of the Unilateral Divorce Laws across States

State	UDL	State	UDL	State	UDL
Alabama	1971	Kentucky	1972	North Dakota	1971
Alaska	1935	Louisiana	/	Ohio	1992
Arizona	1973	Maine	1973	Oklahoma	1953
Arkansas	/	Maryland	/	Oregon	1971
California	1970	Massachusetts	1975	Pennsylvania	/
Colorado	1972	Michigan	1972	Rhode Island	1975
Connecticut	1973	Minnesota	1974	South Carolina	/
Delaware	1968	Mississippi	/	South Dakota	1985
D.C.	/	Missouri	2009	Tennessee	/
Florida	1971	Montana	1973	Texas	1970
Georgia	1973	Nebraska	1972	Utah	1987
Hawaii	1972	Nevada	1967	Vermont	/
Idaho	1971	New Hampshire	1971	Virginia	/
Illinois	/	New Jersey	2007	Washington	1973
Indiana	1973	New Mexico	1933	West Virginia	1984
Iowa	1970	New York	2010	Wisconsin	1978
Kansas	1969	North Carolina	/	Wyoming	1977

Notes: This table reports the year when unilateral divorce law entered into force for each state. The updates to Voena (2015) and Gruber (2004) are taken from Ciacci (2023).

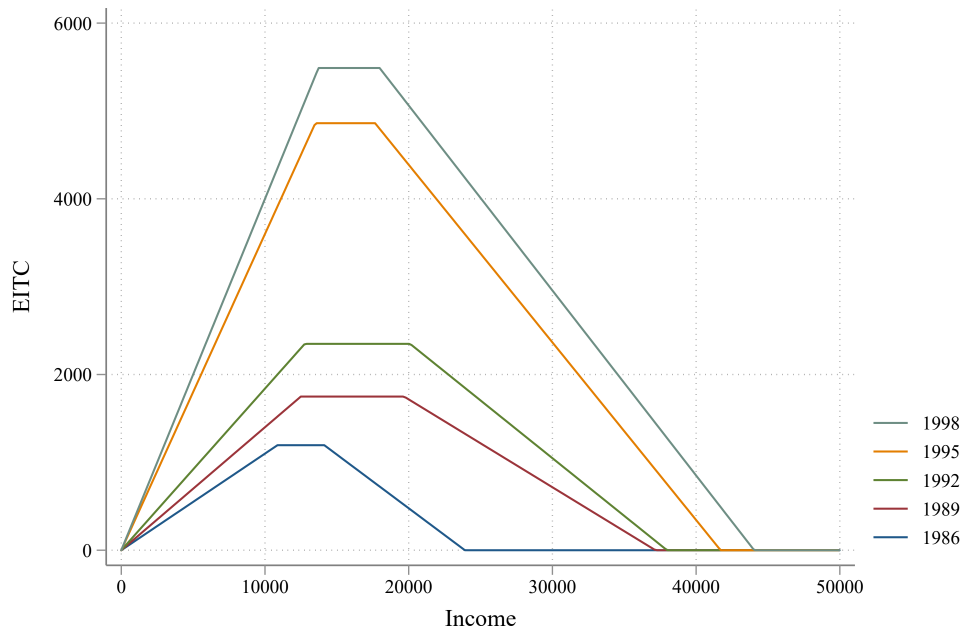
have an adjusted gross income below a specified threshold, which changes over time and with the number of dependent children. The structure of the EITC benefit includes a phase-in period offering a proportional subsidy on earnings, a stable benefit plateau, and a phase-out period where benefits diminish. The federal EITC schedule for families with two children in selected years is depicted in Figure A-1. In our study, we calculate a household's total EITC benefits by adding together the federal and state EITC credits.

I.4 Income Tax System

We follow the recent macroeconomic literature (Heathcote et al., 2017; Borella et al., 2023; Qiu and Russo, 2022) and describe the overall income tax system as:

$$T(Y) = Y - (1 - \lambda)Y^{1-\tau},$$

Figure A-1: Federal EITC Schedules for Families with Two Children (in 2015 Dollars)



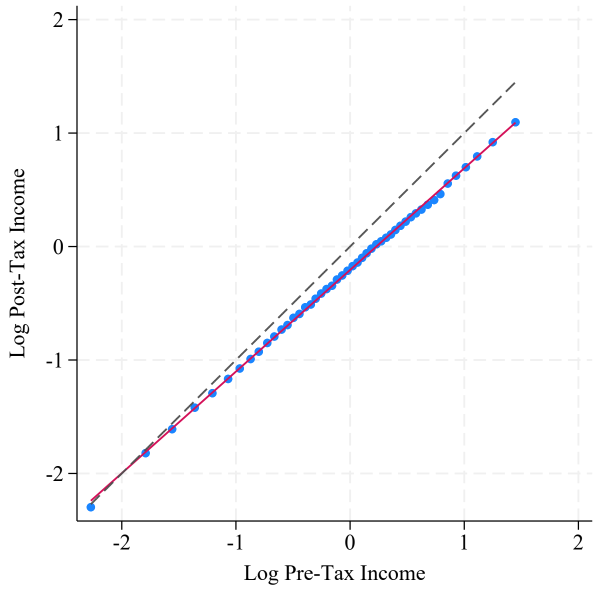
Notes: The figure plots the the federal Earned Income Tax Credit as a function of earned income for families with two children in selected years. Amounts are expressed in 2015 US dollars.

where T denotes taxes and Y total income. The parameter λ governs the average tax rate and the parameter τ captures the degree of progressivity of the income tax system. We estimate the parameters using the logarithm of post-tax income and the logarithm of pre-tax income in each state and in each year. Figure A-2 illustrates that the estimated tax function is a good fit to the data.

Column (2)–(3) and (5)–(6) of Table A-3 report the instrumental variable estimates for industry employment shares, where the female employment share is instrumented by the tax parameters. We use two different sets of IVs, one only with λ and the other with both λ and τ. The resulting point estimates support the previous findings. Quantitatively, we find that as the female employment share increases by 1%, the service share increases by 2.7% to 3.0% and the manufacturing share decreases by 1.7% to 2.2%.

Table A-4 reports the corresponding instrumental variable estimates in the levels specification.

Figure A-2: Goodness of Fit of the Log-Linear Tax Function



Notes: Log post-tax income as a function of log pre-tax income. Each dot is a percentile of the log pre-tax income distribution. The dashed line is the 45 degree line. The solid line is the OLS fitted line.

Table A-3: IV Estimates of the Impact of Female Employment on Industrial Structure

	Service Share			Manufacturing Share		
	(1)	(2)	(3)	(4)	(5)	(6)
Female Share	2.279***	2.681***	3.029***	-2.455***	-1.695***	-2.221***
	(0.155)	(0.154)	(0.145)	(0.225)	(0.187)	(0.174)
Instrument	divorce	λ	λ, τ	divorce	λ	λ, τ
Observations	2040	2040	2040	2040	2040	2040
Weak Id. F	245.17	301.67	206.72	245.17	301.67	206.72

* $p<0.1$, ** $p<0.05$, *** $p<0.01$

Notes: This table reports the instrumental variable estimates where the female employment share is instrumented by divorce rates or the income tax system parameters.

Table A-4: IV Estimates of the Impact of Female Employment on Industrial Structure (Levels)

	Services Employment			Manufacturing Employment		
	(1)	(2)	(3)	(4)	(5)	(6)
Female	1.545***	1.708***	1.898***	-1.161***	-0.762***	-1.037***
	(0.131)	(0.115)	(0.104)	(0.181)	(0.139)	(0.124)
Male	-0.627***	-0.767***	-0.931***	1.270***	0.926***	1.163***
	(0.112)	(0.099)	(0.090)	(0.156)	(0.120)	(0.107)
Instrument	divorce	λ	λ, τ	divorce	λ	λ, τ
Observations	2040	2040	2040	2040	2040	2040
Weak Id. F	101.87	147.89	107.42	101.87	147.89	107.42

* p<0.1, ** p<0.05, *** p<0.01

Notes: This table reports the instrumental variable estimates in absolute size where female employment is instrumented by divorce rates or the income tax system parameters.

I.5 Did the China Manufacturing Trade Shock Induce an Increase in Female Employment and Structural Change?

One potential connection between female employment and structural transformation is that a decline in the price of manufactured goods (e.g. due to faster productivity growth in manufacturing) leads to a decline in male-intensive manufacturing employment. This can induce higher female employment through at least two potentially plausible mechanisms. First, in the face of reduced male employment, women may decide to enter employment and, to the extent that they have a comparative advantage in the service sector, induce an expansion of services. Second, a decline in the price of manufacturing leads to an increase in the demand and price of services. Since services are female labor intensive, the Stolper-Samuelson theorem implies an increase in the wage of female workers, potentially drawing more of them from home production into employment. In this section, we consider the extent to which these effects arise in response to a well-identified exogenous shock to the price of manufactured goods. Specifically, we follow Autor, Dorn and Hanson (2013) and study the effect of the decline in manufacturing prices due to increased import competition from China in the 1990s and 2000s.

We precisely follow Autor, Dorn and Hanson (2013)'s identification strategy, and investigate how the import competition impacts industrial structure and employment across local labor markets. Specifically, we use a shift-share measure of local labor market exposure to import competition, constructed as

$$\Delta IPW_{uit} = \sum_j \frac{L_{ijt}}{L_{ujt}} \frac{\Delta M_{ucjt}}{L_{it}},$$

where L_{it} is the start of period employment in local labor market i and ΔM_{ucjt} is the change in US (subscript u) imports from China (subscript c) in industry j during period t, and the weight is given by its share of national industry employment. We then estimate the following equation:

$$\Delta y_{it} = \gamma_t + \beta_1 \Delta IPW_{uit} + \varepsilon_{it},$$

where y_{it} is some labor market outcome for location i at t, such as manufacturing employment, services employment, male employment, or female employment. To identify the causal effects of the Chinese imports, we follow Autor et al. (2013)'s strategy to instrument the change in import exposure ΔIPW_{uit} by the growth in Chinese imports in eight other high-income markets (Australia, Denmark, Finland, Germany, Japan, New Zealand, Spain, and Switzerland):

$$\Delta IPW_{oit} = \sum_j \frac{L_{ijt-1}}{L_{ujt-1}} \frac{\Delta M_{ocjt}}{L_{it-1}},$$

where ΔM_{ocjt} is the change in imports from China to other developed countries.

Table A-5: IV Estimates of the Impacts of Rising Imports from China

(a) Imports from China and Industrial Structure

	Shares			(log) Levels		
	(1)	(2)	(3)	(4)	(5)	(6)
	Manufacturing	Services	Others	Manufacturing	Services	Others
Δ import exposure	-0.979***	0.367***	0.609***	-0.029***	-0.001	-0.007
	(0.090)	(0.121)	(0.118)	(0.010)	(0.008)	(0.004)
Observations	1444	1444	1444	1444	1444	1444

* p<0.1, ** p<0.05, *** p<0.01

(b) Imports from China and Employment Status by Gender

	Male			Female		
	(1)	(2)	(3)	(4)	(5)	(6)
	Emp/pop	Unemp/pop	NILF/pop	Emp/pop	Unemp/pop	NILF/pop
Δ import exposure	-0.696***	0.190***	0.506***	-0.618***	0.143***	0.475***
	(0.127)	(0.045)	(0.121)	(0.096)	(0.040)	(0.072)
Observations	1444	1444	1444	1444	1444	1444

* p<0.1, ** p<0.05, *** p<0.01

Notes: This table reports the 2SLS estimates of the impacts of rising imports from China on industrial structure and employment. Emp stands for employment, Unemp for unemployment, NILF for not-in-the-labor-force and pop for population. We stack the first differences for the two periods, 1990 to 2000 and 2000 to 2007, for all 722 commuting zones. Robust standard errors in parentheses are clustered on state. Models are weighted by the start-of-period CZ population.

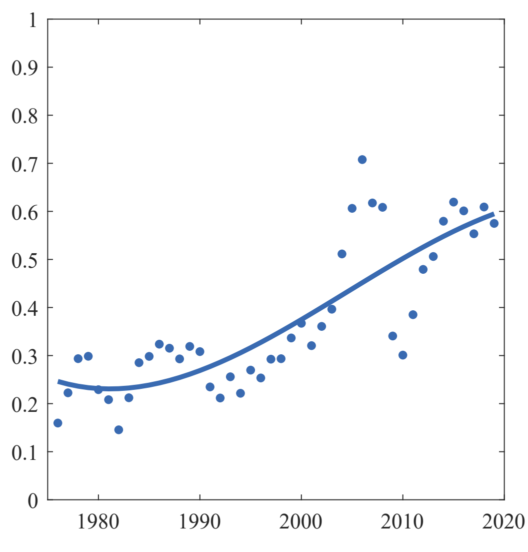
Table A-5 reports the 2SLS estimates, where we use the full sample of 722 commuting zones, and stack the first differences for the two periods (1990 to 2000 and 2000 to 2007). Thus, we have 1444 ($= 722 \times 2$) observations for each specification. The regressions are weighted by the population of each commuting zone at the beginning of the period. Standard errors are clustered at the state level. Panel (a) of Table A-5 shows how the China shock affects the industrial structure. Consistent with Autor et al. (2013), we find that increasing import competition leads to a decline in manufacturing employment. However, we find null effects on the employment in the services or the others sector. The negative employment effect for manufacturing and null employment effects on services and Other mechanically imply a decrease in the employment share of the manufacturing sector and an increase in the shares of the services and the Other sector.

Panel (b) of Table A-5 shows how the China shock affects employment statuses by gender across local labor markets. We find that increasing import competition from China leads to a decline in employment for both men and women, with the magnitude of the decline being somewhat larger for men. About three-quarters of the decline in employment for both men and women is due to transitions out of the labor force, with the remaining quarter due to unemployment.

Thus, we find that a decline in the price of manufacturing goods induced by increased import competition from China did not lead to an increase in service sector employment, nor did it induce a higher female labor force participation. While we find this result interesting, we cannot generalize it beyond the specific experience afforded of the China trade shock. Moreover, the interpretation relies on the same assumption as in Autor, Dorn and Hanson (2013) that equilibrium effects are not too strong, but there is no direct evidence for this. It is also possible that some other events contemporaneous with or induced by the expansion of manufacturing trade with China dampened the demand for services.

II Additional Quantitative Results

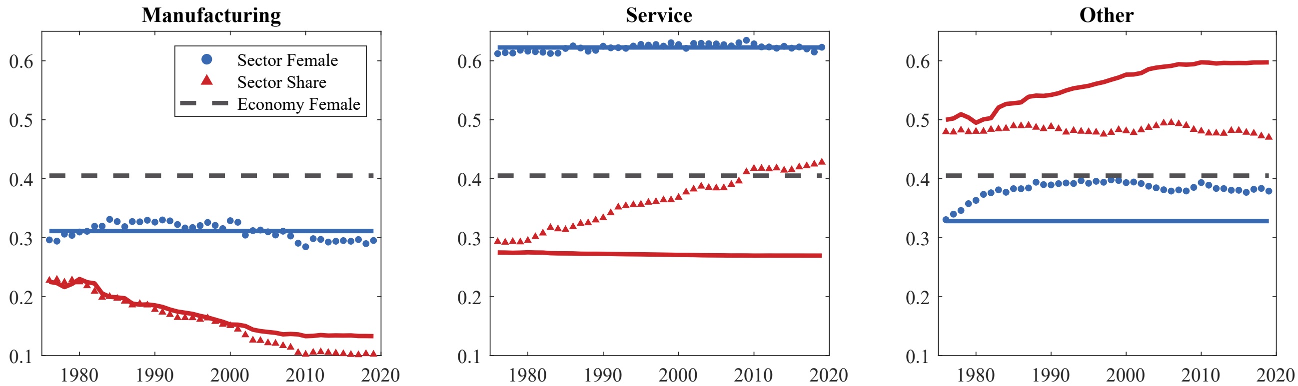
Figure A-3: Gender-Wage Gap



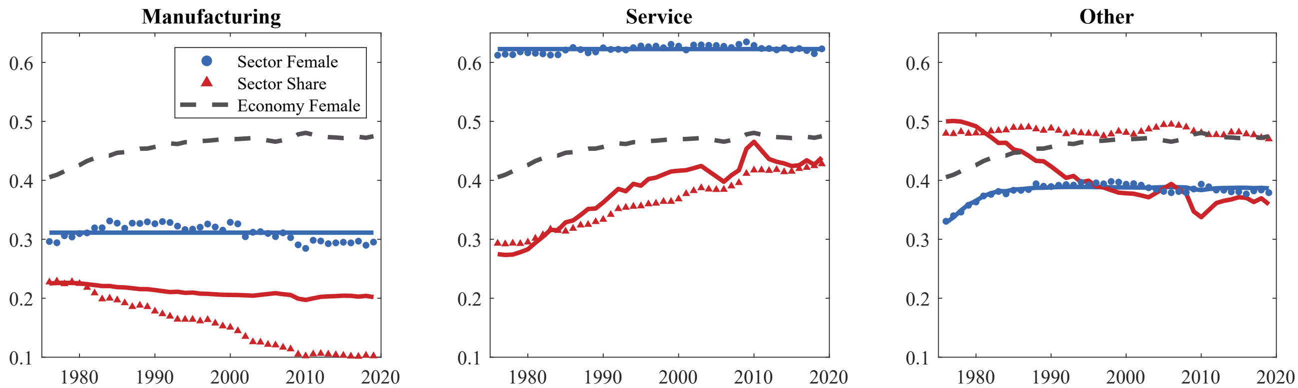
Notes: This figure plots the gender-wage gap in the calibrated model.

Figure A-4: Employment Reallocation in the Counterfactual Economies

(a) Shutting Down Rise in Female Employment



(b) Shutting Down Sectoral Productivity Growth



Notes: This figure plots the employment size of each sector, female employment share of each sector, and overall female share in the counterfactual economies (solid lines). The top row shows the counterfactual experiment of a constant female employment share. The bottom row shows the case of shutting down the differential productivity growth across sectors.

III Aggregation of Quantities and Prices

We are interested in obtaining the quantities and prices for the three broad sectors, i.e., manufacturing, services, and others, while the BEA only reports the quantities and prices of disaggregated industries. Moreover, since real quantities of different sectoral outputs are not additive, one cannot obtain the real quantity of an aggregate sector by simply summing up the real quantities of the disaggregated industries it consists of. Thus, we need an appropriate aggregation procedure to obtain the real quantities of the aggregate sectors. We follow Herrendorf et al. (2013) by using the so-called cyclical expansion procedure.

Denote $Y_{it}, y_{it}, Q_{it}, P_{it}$ the nominal value-added, real value-added, chain-weighted quantity index, and chain-weighted price index for industry i at time t, respectively, which could be obtained from the BEA. We pick a base year such that the chain-weighted quantity and price indices are normalized to $Q_{ib} = 1$ and $P_{ib} = 1$. By definition,

$$Y_{it} = P_{it} Q_{it} Y_{ib}, \quad y_{it} = Q_{it} Y_{ib}.$$

For an aggregate sector s that encompasses several industries, the nominal value-added is simply the sum of the nominal value-added of each component industry $Y_{st} = \sum_{i \in s} Y_{it}$, but the real value-added is not additive, i.e., $y_{st} \neq \sum_{i \in s} y_{it}$. For appropriate aggregation, we proceed by the "chain-summation" method:

$$\frac{Q_{st}}{Q_{st-1}} = \sqrt{\frac{\sum_{i \in s} P_{it-1} y_{it}}{\sum_{i \in s} P_{it-1} y_{it-1}} \frac{\sum_{i \in s} P_{it} y_{it}}{\sum_{i \in s} P_{it} y_{it-1}}},$$

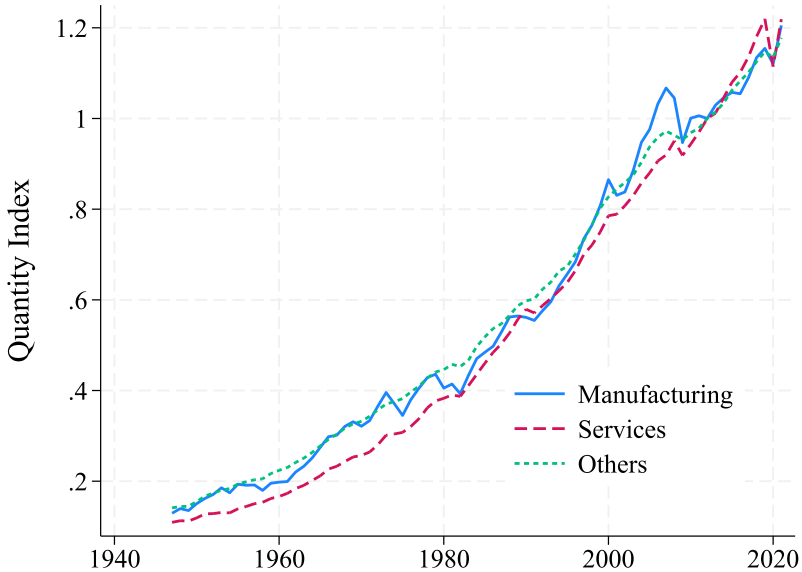
from which we could obtain the correctly aggregated quantity index iteratively as

$$Q_{st} = \frac{Q_{st}}{Q_{st-1}} \frac{Q_{st-1}}{Q_{st-2}} \cdots \frac{Q_{sb+1}}{Q_{sb}} Q_{sb},$$

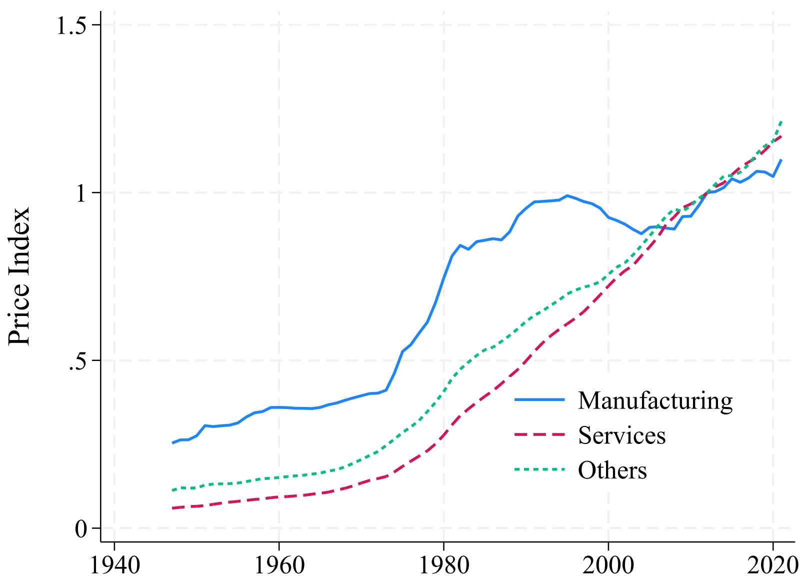
where Q_{sb} is normalized to 1. The aggregated real value-added of sector s is therefore $y_{st} = Q_{st} Y_{sb}$, and the aggregated price index of sector s is $P_{st} = Y_{st}/y_{st}$. Figure A-5 plots the aggregated chain-weighted quantity and price indices for manufacturing, services, and Other sector.

Figure A-5: Aggregated Quantity and Price Indices

(a) Quantity Indices



(b) Price Indices



Notes: The figure plots the chain-weighted quantity (top) and price (bottom) indices for the three aggregated sectors. The base year is set to 2012.