A Study of the Long-run Substitutability Between Men and Women

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Abstract

Using a variable elasticity of substitution (VES) framework, this study estimates the long-run elasticity of substitution between US male and female workers, specifically, the slope of the inverse demand curve for male workers relative to female workers. Our 2SLS approach exploits possible exogenous sources of change in state employment induced by national employment growth. We find that the long-run elasticity of substitution between male and female workers is close to 1.7 and show that this estimate is robust across a wide range of model specifications. Using this estimated elasticity of substitution parameter, we find that approximately 7% of the fall in the gender wage gap can be explained by a steep increase in the relative female labor supply during the period 1980-2014.

Keywords: Elasticity of substitution, VES and CES production functions, gender wage gap.

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1 Introduction

Over the past three decades, economists have tested a variety of explanations for the persistent employment and earning differentials between men and women (Blau and Kahn (2016)). Some of the popular explanations include labor force participation (Juhn and Murphy (1997), Goldin (2006), Blau and Kahn (2007), Blau and Kahn (2013)), occupational choice (Levanon et al. (2009), Goldin (2014)), work time flexibility (Rosen (1986), Altonji and Blank (1999), Goldin (2014)), self-selection (Blau and Kahn (2006), Mulligan and Rubinstein (2008)), education and college major (Black et al. (2008), Becker et al. (2010)), non-cognitive skills (Cotter et al. (2011), Borghans et al. (2014), Fortin (2015)), impact of motherhood (Correll et al. (2007), Albanesi and Olivetti (2009)), labor market discrimination (Black (1995), Bertrand et al. (2005)), personal traits and psychological attributes (Bertrand (2011)). Kaufman (2010) argues that despite the large volume of research in this area, there are still unanswered questions and some critical shortcomings in the commonly used research designs.

Figure 1 shows that the relative female-male wage ratio has increased by approximately 18% and the relative female-male labor force participation rate has increased by approximately 12% between 1980 and 2014. These ratios also share very similar time trends. To identify the impact of this steep increase in relative female labor force participation rates on the gender wage gap, we estimate the long-run elasticity of substitution between men and women because it captures the impact of an increase in the relative share of female workers on the average relative returns. Moreover, the elasticity of substitution parameter shows the extent to which the differences in the relative labor supply between men and women can explain the differences in average labor productivity. Also, using this parameter, we provide an estimate of how much of the fall in the gender wage gap was due to the 12% increase in the relative female labor supply for the period 1980-2014.

Earlier studies of substitution between different groups of workers based on sex, age and other demographic traits, including Johnson (1970), Berndt and Christensen (1974), Anderson (1977), Welch and Cunningham (1978), Grant (1979) and others, showed the existence of substantial important interactions in the production process between various labor inputs. Grant and Hamermesh (1979) provide a critical synthesis of econometric estimates examining substitution between women and youth. Freeman (1979), Berger (1983), and Hamermesh (1984) find that the increase in the labor force participation rate had a negative impact on male earnings in the period 1970-1980.

Grant and Hamermesh (1981), Borjas (1983), and the survey by Hamermesh (1986) emphasize the importance of neoclassical production technology in empirical estimations of substitutability between two labor inputs. By investigating the sensitivity of labor demand functions, Borjas (1986) empirically shows that labor demand functions are, in general, robust to major specifications. Costrell et al. (1986) use Satio's two-level CES production function to measure the substitution in production for major age-sex groups in ten industries for the period 1958-1975. In a more recent study, Giorgi et al. (2015) provide an estimate of the short-run elasticity of substitution between Italian men and women in 1993-2006.

One of the main challenges to estimating the elasticity of substitution between male and female workers is that male-female relative wage ratios and male-female relative labor supply ratios are determined simultaneously by demand and supply. Therefore, we need to solve the standard identification problem to estimate the slope of the inverse demand curve for male workers relative to female workers. Hamermesh (1993) argues that any empirical study that does not address this identification problem could obtain misleading results. To address this simultaneity between the male-female relative wage and labor supply ratios, Acemoglu et al. (2004) exploit the World War II US mobilization rate as a natural experiment that forced a large number of women into the labor market. The variations in cross-state mobilization rates are used as instruments for the relative female labor supply.

We identify the long-run elasticity of substitution between male and female workers in US state-level data from 1980-2014 by exploiting regional variations in industry-level changes in employment induced by national employment growth. Our local labor market approach of identifying the possible exogenous sources of variations in the relative female labor supply is based on the early work of Bartik (1991), which was then popularized by Blanchard and Katz (1992), who emphasize the role of industry structure in regional economic outcomes, and by the more recent work of Autor and Duggan (2003) and Autor et al. (2013).[1] Therefore, our cross-sectional variations in the predicted change in employment come from the regional demographic composition of workers by industry. A potential concern of this approach is that states' industry composition may be correlated with their unobserved local labor market conditions. To address this concern, we also follow the approach proposed by Autor et al. (2013) and use a 5-year lag of the industry employment share to construct a modified version of Bartik instruments.[2]

One of the major sources of the changes in labor force composition over the past three decades is the skill-biased technological change that replaced many labor-intensive tasks (Acemoglu (1998, 2002a,b), Acemoglu and Autor (2011) and others).[3] This disproportionate growth in skill-intensive industries has positively affected the relative female labor supply ratio because since 2003, data show that women achieve higher levels of education than men (Goldin (2006)). Therefore, our predicted state employment growth, which is generated from the regional variations in industry composition, is highly correlated with relative female labor supply ratios.

In our conceptual framework, we consider both CES and VES production functions and choose the appropriate specifications based on the data using the Box-Cox transformation. The main difference between the two approaches is that the VES framework allows the elasticity of substitution between men and women to vary with their relative supply. Our 2SLS estimates of the long-run elasticity of substitution between male and female workers lie between 1.67 and 1.72. To check whether this estimate is sensitive to the choice of production function, we compare our results with those from the CES and translog production functions.

[1] There are a large number of studies in labor economics and other economics fields using Bartik instruments.

[2] We also provide several pieces of evidence that support the validity of our instruments in different robustness exercises.

[3] This phenomenon is not restricted to the US. Dao et al. (2017) show that the unskilled labor share declined in 29 large countries including the US during the period 1991-2014.

Using an instrumental variable approach, Acemoglu et al. (2004) find that the elasticity of substitution parameter varies between 1 and 1.5 for the period 1940-1990. This result suggests that although Acemoglu et al. (2004) use an approach different from ours to address the potential endogeneity of the relative female labor supply, the long-run elasticity of substitution estimates in both approaches are comparable. The 2SLS point estimate of the long-run elasticity of substitution from the VES, 1.72, implies that the relative male-female wage ratio decreases approximately 0.58 ($\equiv 1/1.72$)% due to a 1% increase in the relative female labor supply.

Since the relative female labor supply ratio has increased approximately 12% during the 1980-2014 period, our preferred VES estimate of the elasticity of substitution parameter suggests that the gender wage gap has fallen approximately 7% due to the steep increase in the relative female labor supply. Using different model specifications, as well as various production functions, we find that our estimates are robust. Therefore, the main contribution of this study to the literature is that it provides an estimate of the long-run elasticity of substitution between male and female workers for the period 1980-2014. Estimating the heterogeneous impacts of relative female labor supply ratios on the relative wage, we find that the elasticity of substitution parameter is much higher for relatively older cohorts.

The structure of the paper is as follows. Section 2 presents the theoretical framework of both the CES and VES production functions. Section 3 discusses the data and construction of instruments. We present our main estimation results for the long-run elasticity of substitution parameter and the robustness checks for the validity of instrumental variables. We conclude in Section 5. All the derivations are shown in the Appendix.

2 Theoretical Framework

Let us consider the following aggregate production function with only two inputs, male (N_m) and female (N_f) workers:

$$Q_{st} = F\Big(N_{mst}, N_{fst}\Big) \tag{1}$$

where N_{mst} and N_{fst} are the number of employed male and female workers in state s at period t. We assume that F is homogeneous of degree 1 in N_m and N_f and continuously differentiable in all its arguments and also that it has isoquants that are downward sloping and concave in $N_m - N_f$ space. Suppose $F(\cdot)$ follows the CES specification; then equation (1) can be written as

$$Q_{st} = \Big(\theta_{st}\big(a_{st}N_{mst}\big)^{\kappa} + (1-\theta_{st})\big(b_{st}N_{fst}\big)^{\kappa}\Big)^{1/\kappa} \tag{2}$$

where a_{st} and b_{st} represent gender-augmented technological change, θ_{st} is a time-varying technology parameter, and κ is a time-invariant production parameter.

The elasticity of substitution between male and female workers is defined as the percentage decrease in relative demand for male workers, N_{mst}/N_{fst}, in response to a 1% increase in their relative wage, $\mathrm{w}_{mst}/\mathrm{w}_{fst}$. The elasticity of substitution between male and female workers σ for the CES production function is given by

$$\sigma = \frac{1}{1-\kappa} \tag{3}$$

The defining feature of the constant elasticity of substitution production function is that σ does not vary with the input ratio, that is, $d\sigma/dn = 0$ where $n = N_{mst}/N_{fmst}$. We assume that male and female workers are paid according to their marginal product, and this assumption leads to the following log-linear relationship between male-female wages and labor supply ratios:

$$\ln\left(\frac{\mathrm{w}_{mst}}{\mathrm{w}_{fst}}\right) = \frac{1}{\sigma}\left[D_{st} - \ln\left(\frac{N_{mst}}{N_{fst}}\right)\right] \tag{4}$$

where D_{st} indexes relative demand shifts favoring male workers and measured in log quantity units.[4]

Whether σ is a constant or if it varies with the male-female input ratios is an empirical question because, in principle, the elasticity of substitution need not be necessarily a constant for a given level of output. Allen (1956) shows that any ad hoc assumptions about the value of σ can lead to a specification bias. Therefore, we consider an alternative of the CES production function, namely, the VES production function, because it is a variant of the CES production function and allows the elasticity of substitution parameter (σ) to vary with output and input combinations (Hicks (1948)). There are several other specific functional forms such as generalized Diewert (1971), the translog form Christensen et al. (1973) and the Pollak et al. (1984) that also make second-order approximations of the production function. Therefore, like the VES, each of these production functions has the advantage over the CES function that σ is not restricted to being a constant but instead depends on the input ratios.[5]

When $F(\cdot)$ follows the VES specification, we obtain from equation (1)

$$Q_{st} = \gamma N_{mst}^{\alpha(1-\delta\rho)} \Big[N_{fst} + (\rho - 1) N_{mst} \Big]^{\alpha\delta\rho} \tag{5}$$

The positive constant γ is called the efficiency parameter. It captures the skill-neutral technological improvements that affect both labor inputs in the same proportion, α is a time-invariant production parameter, ρ is a time-varying substitution parameter between male and female workers, and δ is a time-varying technology parameter that can be interpreted as indexing the share of work activities allocated to male and female workers. Therefore, the time-varying parameter $\delta\rho$ captures any technological improvements that affect the productivity of male and female workers asymmetrically. By making the assumption $0 < \delta\rho < 1$, we rule out the possibility that there exists a gender-augmented technology that makes any particular gender group irrelevant in the production process.

[4] The expression D_{st} is $\ln(\theta_{st}/(1-\theta_{st})) + \kappa \ \ln(a_{st}/b_{st})$. See Autor et al. (2008) for details.

[5] In the sensitivity analysis of the choice of production functions, we will also consider one of these generalized production functions to check the robustness of our results.

Revankar (1971) shows that the VES production function satisfies many properties of a neoclassical production function, as the MRTS (marginal rate of technical substitution) is a decreasing function of N_{fst}/N_{mst}.[6] The VES production function also includes the Harrod-Domar fixed coefficient model ($\rho = 0$), the Cobb-Douglas function ($\rho = 1$) and the linear production function ($\rho = 1/(\delta > 1)$) as special cases. Thus, as ρ increases from 0 to $1/(\delta > 1)$, σ increases steadily from zero to infinity. The elasticity of substitution parameter for the VES production is

$$\sigma = 1 + \left(\frac{\rho - 1}{1 - \delta\rho}\right)\frac{N_{mst}}{N_{fst}} = 1 + \psi \times \left(\frac{N_{mst}}{N_{fst}}\right) \tag{6}$$

where $\psi = (\rho - 1)/(1 - \delta\rho)$. Therefore, σ for VES varies linearly with the relative female-male labor supply ratios around the intercept term of unity and the slope parameter ψ.

Again, the assumption that in market equilibrium, workers are paid according to their marginal product of labor yields the following relationship between relative wages and relative labor supply ratios:

$$\begin{aligned} \frac{\mathrm{w}_{mst}}{\mathrm{w}_{fst}} &= \left(\frac{\rho - 1}{1 - \delta\rho}\right) + \left(\frac{1 - \delta\rho}{\delta\rho}\right)\left(\frac{N_{fst}}{N_{mst}}\right) \\ &= \beta_0 + \beta_1\left(\frac{N_{fst}}{N_{mst}}\right) \end{aligned} \tag{7}$$

where $\beta_0 = (\rho - 1)/1 - \delta\rho$ and $\beta_1 = (1 - \delta\rho)/\delta\rho$. Thus, substituting β_0 and β_1 in equation (6), we obtain,

$$\sigma = 1 + \left(\frac{\beta_0}{\beta_1}\right)\left(\frac{N_{mst}}{N_{fst}}\right) \tag{8}$$

Equation (8) shows that the relative female-male labor supply ratios affect the elasticity of substitution between male and female workers in two ways: through β_0/β_1 and N_{mst}/N_{fst}.

[6] We show the expression for the MRS in the Appendix.

2.1 A Comparison Between the CES and VES Frameworks

Both the CES and VES production functions maintain the linear homogeneity property; the main difference between them is that the VES specification allows various ways to choose the functional dependence of σ on the outputs and inputs. Since σ is a constant in CES, the elasticity of substitution is the same at all points of an isoquant. By contrast, the VES allows σ to vary monotonically with the input ratio along an isoquant whenever $\rho \neq 0$. If $\rho = 0$, the VES specification reduces to the Cobb-Douglas case. Another property of VES is that σ is the same along a ray through the origin.

In an empirical setup, the choice between the CES and VES specifications depends on the relationship between male-female wage ratios and labor supply ratios because the CES specification is log linear and the VES specification is linear. In our particular setting, there is no a priori economic rationale for preferring one specification over the other. In the existing literature, researchers most frequently use the CES specification by assuming that the relationship between factor proportions and factor price ratios is indeed log linear. However, following Lovell (1973), we use the Zarembka (1968) test, which is specifically designed to distinguish between the linear and log-linear functional forms of a postulated relationship. The Zarembka (1968) test applies the Box-Cox transformation and estimates the transformation parameter to choose between the linear and log-linear functional forms.

Consider the following relationship between male-female wage ratios and labor supply ratio

$$\left(\frac{\mathrm{w}_{mst}}{\mathrm{w}_{fst}}\right)^{\lambda} = a_0 + a_1 \left(\frac{N_{fst}}{N_{mst}}\right)^{\lambda} \tag{9}$$

where λ is the transformation parameter. Equation (9) defines a whole class of production functions, two of which are CES and VES. As $\lambda \to 0$, (9) approaches (4), which is the CES cost minimization side relation; if $\lambda = 1$, (9) reduces to (7), which is the VES side relation.

We can rewrite equation (9) as

$$\left(\frac{(\mathrm{w}_{mst}/\mathrm{w}_{fst})^{\lambda}-1}{\lambda}\right)=b_0+b_1\left(\frac{(N_{fst}/N_{mst})^{\lambda}-1}{\lambda}\right) \tag{10}$$

By adding a disturbance term to equation (10), we can estimate λ in a non-linear least squares setting to choose the appropriate model specification between CES and VES.[7]

3 Empirical Approach

3.1 Data

We use current population survey (CPS) data, which contain income and demographic information for individual workers. The data are drawn from 5 percent self-weighted outgoing rotation group (ORG) supplements of the 1980-2014 samples. The data consist of US-born women and men, aged 18-65, with positive annual earnings and hours worked in the preceding year and a nonzero sampling weight. The earnings measure used is the annual wage. Annual earnings are expressed in 2000 US dollars by using the personal consumption expenditures price index. State-level control variables such as poverty rate, unemployment rate, state GDP, total population and state minimum wage are obtained from the University of Kentucky Center for Poverty Research welfare data. We merge these two data sets by state. Therefore, we have 51 observations in each year and a total 1,785 state-level observations for the period 1980-2014.

The summary statistics are shown in Table 1. We report the mean and standard deviation of all the variables for the period 1980-2014. The left vertical panel shows the time variations in the relative wage and labor supply ratios in three different time periods: 1980-1990, 1990-2000 and 2000-2014. The right vertical panel shows the cross-sectional variations of these variables

[7]Note that equation (10) represents a wide range of model specifications depending on the value of λ. However, we use this Zarembka (1968) test only to distinguish between CES and VES specifications by estimating the value of λ whether it approaches 0 or 1. Once we choose the appropriate model based on the λ estimates, we use either equation (4) or equation (7) to estimate the elasticity of substitution between male and female workers.

for four regions: northeast, midwest, south and west.[8] We note that there are very large variations in the relative female labor supply ratios across the three different time periods as well as across the four regions. We exploit these time and cross-section variations to estimate the long-run elasticity of substitution between male and female workers.

3.2 Model

In Table 2, we report the estimated Box-Cox transformation parameter and the 95% confidence interval from the non-linear least squares. The left panel shows the estimates without using any control variables, and in the right panel, we include the state control variables listed in Table 1. The Box-Cox transformation parameter estimate is 0.94 in column 1, and it changes to 1.29 when we include the control variables. These results suggest that the Box-Cox transformation parameter is closer to 1 than 0. Therefore, the relationship between the relative wage and labor supply ratios is most likely not log linear in our sample data, and hence we use the VES specification over the CES production function. In a robustness exercise, we also use the CES to check whether the results from the VES are sensitive to the choice of production function.

Since our dependent variable is the relative male-female wage ratio, we implement the Autor et al. (2008) approach to estimate the composition adjusted relative wage.[9] Following the Katz and Murphy (1992) approach, we substitute the unobserved demand shifts by using a linear time trend (D_t) to estimate equation (7). Thus, our model specification is given by,

$$\frac{\mathrm{w}_{mst}}{\mathrm{w}_{fst}} = \beta_0 + \beta_1 \left(\frac{N_{fst}}{N_{mst}} \right) + \beta_2 \, D_t + \beta_4 \, X_{st} + \eta_s + \varepsilon_{st} \tag{11}$$

where X_{st} is a set of state-level control variables, and η_s are the state fixed effects. The estimates of β_0 and β_1 in equation (11) are used to calculate the elasticity of substitution (σ) between male and female workers. The simplest way we can estimate β_0 and β_1 in equation (11) is using the simple ordinary least squares method. However, the relative male-female

[8]The CPS data provide 8 classified regions; we further clustered them into 4.
[9]See Autor et al. (2008), Appendix for details.

labor supply ratios are likely to be correlated with unobserved local labor market economic conditions. We therefore use the instrumental variable estimation method.

3.3 Instruments

Our instrumental variable approach is based on plausibly exogenous sources of state employment growth. Following the approach proposed by Bartik (1991) and then used by Blanchard and Katz (1992), Currie and Gruber (1996a,b), Bound and Holzer (2000), Gould et al. (2002), Autor and Duggan (2003), Acemoglu et al. (2010), Autor et al. (2013), among others, we use cross-state differences in industrial composition and national changes in employment to predict each state's employment growth.

The Bartik instruments are constructed by estimating the state employment growth, which is generated by interacting state variations in industry employment share with the national industry employment growth rate. Suppose we have K industries; then, Bartik instruments estimate the predicted change in log employment $\widehat{B}_{st}$ of a state s between the years t_0 and t_1 as

$$\widehat{B}_{st} = \sum_{k=1}^{K} \varphi_{skt_0} \times \vartheta_{\cancel{s}kt_1} \tag{12}$$

where φ_{skt_0} is the employment share in industry k in state s at period t_0. Following the notation from Autor and Duggan (2003), we denote $\vartheta_{\cancel{s}kt_1}$ as the national average of the log change in two-digit industry k's employment share. Note that the subscript $\cancel{s}$ in $\vartheta_{\cancel{s}kt_1}$ indicates that we exclude each state's employment to calculate the change in national employment growth.

Since this measure of predicted regional employment growth exploits the regional variations in local labor market composition by industry, we expect it to be highly correlated with the long-run upward trend in the relative female labor supply ratios.[10] Appendix Table 2 presents first-stage estimates for different model specifications. We find that the employment growth in the professional and related service industry can strongly predict the steep increase in

[10] In subsection 4.1, we explain the mechanism behind the substantial predictive power of our instruments to explain the variations in relative female labor force participation rate.

the relative female labor supply. The first-stage adjusted R^2 varies between 0.25 and 0.46, suggesting that our instruments can explain a considerable amount of the variation in the relative female labor supply ratio during the period 1980-2014.

Equation (12) suggests that the difference in predicted employment growth across states stems almost entirely from the variations in the regional industry employment structure in period t_0. Therefore, the validity of the Bartik instruments relies on the exogeneity of the location-specific industry share, not the national employment growth rate. An intuitive argument supporting this claim is that national industry growth rates avoid correlation with local economic conditions (Autor and Duggan (2003)). Therefore, the role of the national employment growth rates in the Bartik instrument stems from their relevance, not exogeneity (Goldsmith-Pinkham et al. (2018)).

Autor et al. (2013) argue that the variation in industry employment share is generated from two sources: the differential concentration of employment in manufacturing versus non-manufacturing jobs and specialization in import-intensive industries within local manufacturing. Thus, a potential concern regarding the validity of the Bartik instrument is that if some component of the industry-level employment growth rates depends on state-specific unobserved labor market conditions in a way that is proportional to a state's industry composition, then the Bartik instruments are invalid. Therefore, the Bartik instruments fail the exogeneity condition when the error terms in equation (11) are correlated with industry composition and not because of national employment growth rates.

To address this potential concern, we follow an approach similar to that of Autor et al. (2013) and use a 5-year lag of industry employment share to avoid any type of potential contemporary correlation between the error term and industry composition.[11] Thus, our

[11] To estimate the effects of import competition on wages and employment in the US local labor market, Autor et al. (2013) use Bartik instruments to construct regional variation in exposure to trade with China. Specifically, their Bartik instruments consist of the canonical product of commuting zone-specific industry composition and growth in the imports of other high-income countries from China. To avoid any kind of anticipation effect, Autor et al. (2013) use a decade lag of commuting zone-specific industry composition. To address the validity of the Bartik instruments, Goldsmith-Pinkham et al. (2018) discuss an alternative approach by using the Rotemberg (1983) weights. This approach is based on the Andrews et al. (2017)

predicted change in employment ($\Delta\widehat{E}_{st}$) in state s at year t is given by

$$\Delta\widehat{E}_{st} = \sum_{k=1}^{K} \varphi_{skt_0-5} \times \vartheta_{\cancel{s}kt_1} \tag{13}$$

where $\theta_{sk(t_0-5)}$ is the employment share in industry k in state s at period $t_0 - 5$. This measure of predicted regional employment growth in period t can also work as an instrument because it is mainly determined by local labor market composition five years prior to t. Therefore, we expect it to be correlated with the long-run component of the relative female labor supply ratio but uncorrelated with contemporaneous unobserved local labor market conditions reflected in ε_{st}. The results of this robustness exercise are reported in Appendix Table 3, and they show that our estimation results are robust across the above two measures of predictive changes in state employment.

A second potential concern of our identification is that state employment growth can be highly correlated with the state political economy. Although we include state fixed effects, these capture only any state or substate-level time-invariant political economy effects on relative female labor force participation rates. Therefore, the concern is that our estimation results are driven by any time-varying political economy responses that affect both relative female labor force participation and the industry component of the growth rate in some states. In our robustness exercises, we use different combinations of state political variables to check the sensitivity of our results.

A third threat to identification is related to the exclusion restriction, which requires that changes in state employment growth affect the relative male-female wage ratios only through the relative female labor supply ratios conditioned on a set of state economic and demographic variables. Although we have a rich set of state control variables, the concern is whether state employment growth affects the relative male-female wage ratios through unobserved local labor market conditions. Therefore, the question is whether our instrumental variables are correlated with the unobserved determinants of relative male-female wage ratios that are swept

sensitivity analysis of parameter misspecification.

into the second stage residuals. To address this concern about the exclusion restriction, we report the Sargan-Hansen overidentification test statistics for each 2SLS model specification and also perform some additional robustness checks, which are discussed in Section 4.

4 Estimates

4.1 The Impact of Heterogenous Employment Growth on Relative Female Labor Supply

Our instrumental variable strategy, outlined in Section 3, identifies the component of the changes in the relative female labor supply that is due to the state employment growth induced by national employment growth. One of the major sources of national employment growth over the last three decades is advancements in technology. However, skill-biased technological change creates heterogeneous employment growth because it creates a demand for skilled labor by automating labor-intensive jobs (Autor et al. (1998), Acemoglu (1998, 2002a), Acemoglu and Autor (2011)).[12] Autor et al. (2017) investigate why the share of unskilled workers declined in sectors such as wholesale trade, retail trade and utilities.[13] Autor et al. (2013) show that employment in US manufacturing industries is negatively affected by the increasing imports from China, and traditionally men represent a larger fraction of the labor force in this industry.

The relative female labor supply has been positively affected by this disproportionate growth in skill-intensive industries because all over the world, there has been remarkable growth in the number of women accessing higher education over the last 40 years (Becker et al. (2010)). In particular, women outperformed men in terms of receiving higher education in the US. The college enrollment gender gap started shrinking in the early 1950s, and by 2003,

[12] Another major source of the disproportionate growth in employment is international trade. Elsby et al. (2013) argue that the decline in labor share in most US industries is strongly related to trade and international outsourcing.

[13] In a similar study, Autor and Dorn (2013) investigate how the growth of low-skilled jobs in the service sector has affected US wage inequality.

there were 1.35 females for every male who graduated from a four-year college; this trend plays a major role in the steep increase in the female labor force participation rate (Goldin (2006), Goldin et al. (2006)). Therefore, the upward trend in the overall level of women's schooling and the labor force participation rate are highly correlated with the skill-biased technological change (Goldin et al. (2008)). This mechanism explains why we expect that our instruments have some predictive power to explain the growth in the relative female labor supply.

Figure 2 sketches this identification strategy. The top panel of Figure 2 reveals that our instruments have substantial predictive power to explain the increase in the relative female labor supply. The first-stage coefficient is close to unity, with a t-ratio of 39, suggesting a strong positive correlation between the predicted and actual relative female labor supply. The bottom panel plots a reduced form (OLS) regression of the changes in the relative male-female wage ratio, showing a substantial reduction. This strong negative relationship is expected because of the disproportionate growth of the relative female labor supply in skill-intensive occupations.[14]

4.2 The Impact of the Relative Female Labor Supply on the Relative Wage Ratio

In Table 3, we report the estimates of the long-run elasticity of substitution (σ) between male and female workers using the VES production function. The state-level clustered standard errors are reported in parentheses. The first column uses the log relative male-female labor supply ratio as the only explanatory variable, along with the state fixed effects. The second column uses the specification of Katz and Murphy (1992) by adding a linear time trend to the column 1 model specification. The 2SLS estimate of σ in the Katz and Murphy (1992) model is 0.78, and the adjusted $R^2 = 0.45$. Hence, the simple Katz and Murphy (1992) model can explain a large variation in the relative male-female wage ratios.

[14]The first-stage regression results are reported in Appendix Table 2 and in addition, we report the first-stage F-statistics for each 2SLS regression in Table 3.

We add two state economic factors, poverty and unemployment, in addition to the Katz and Murphy (1992) model in column 3 and find that the coefficient of the female-male relative labor supply ratio changes from -3.31 to -1.48. In column 4, we drop poverty and unemployment and add state minimum wage, log population, log GDP and inter-state migration in addition to the Katz-Murphy model. We note that these four state economic factors can explain a considerable amount of the variations in male-female relative wages. Compared to the Katz-Murphy model specification in column 2, the adjusted R^2 increases from 0.45 to 0.80, and the estimated elasticity of substitution values change from 0.74 to 1.67. The p-value of the Sargan-Hansen test statistic, 0.16 in column 4, suggests that at a 5% significance level, we cannot reject the null hypotheses that our instruments are jointly exogenous.

Column 5 of Table 3 includes all six state economic control variables, and that is our most robust model specification. As shown, the point estimate of the long-run elasticity of substitution between male and female workers from the VES production function is 1.72. Since the elasticity of substitution parameter measures the slope of the inverse demand curve for male workers relative to female workers, we can interpret $\sigma = 1.72$ as meaning that a 1% increase in the relative female labor supply decreases the male-female wage ratio by approximately 0.58 ($\equiv$1/1.72)%. The 2SLS point estimates are reasonably stable in columns 4 and 5, in which we include all key state economic variables along with the time trend, demographic variables and state fixed effects. The 2SLS coefficients are also statistically significant even at a 1% significance level. Therefore, $\sigma = 1.72$ is our preferred point estimate of the long-run elasticity of substitution between male and female workers.

One way to gauge the economic magnitude of these effects is to compare the estimated elasticity of substitution parameter with those from previous studies. Acemoglu et al. (2004) use an instrumental variable approach to provide a causal estimate of the long-run elasticity of substitution between male and female workers and find that it varies between 1 and 1.5 for the period 1940-1990. Thus, our estimated elasticity of substitution from the VES production function is comparable to Acemoglu et al. (2004). In addition, our estimated range of σ is also comparable to commonly accepted values of the elasticity of substitution between skilled and unskilled workers.[15]

There are three potential sources of the differences between our preferred $\hat{\sigma} = 1.72$ and Acemoglu et al. (2004) estimates: (i) choice of instruments, (ii) the production function framework, and (iii) the sample period. Our instruments are comparable to Acemoglu et al. (2004) because in both scenarios, local labor market conditions are used to construct instruments for relative female labor supply ratios, and in a robustness exercise, we show that our results are not sensitive to the choice of production function. Therefore, the difference between our estimate and Acemoglu et al. (2004) is probably due to the two different time periods we consider.

Table 4 reports the estimated elasticity of substitution parameters from the VES production function by state. To obtain $\hat{\sigma}$ for each state, we use the equation (8) expression, σ. The ratio β_0/β_1 is obtained from the Table 3 2SLS column 5 model specification (contains all key state control variables), and the relative male-female labor supply ratios (N_m/N_f) are calculated by each state's average relative labor supply ratio for the entire sample time period, 1980-2014. It can be seen that a 1% increase in the relative female labor supply can decrease the male-female wage ratio relatively more in many southern states compared to some of the western and eastern states, most likely because the female/male labor supply ratios in many southern states are relatively lower than those in some western and eastern states.

In the left panel of Figure 3, we show the scatter plot for relative male-female labor supply and relative wage ratios for all 51 states. Each dot represents the equilibrium outcome of these two variables generated from the interaction between male-female relative labor demand and the labor supply curves in a particular state's labor market. Using the instrumental variable estimation strategy, we estimate the slope $(1/\sigma)$ of the relative male-female labor demand curve at different values of the male-female labor supply ratios and plot them in the right

[15] Using US data, the estimated elasticity of substitution between skilled and unskilled workers by Johnson (1970) is 1.34, by Katz and Murphy (1992) is 1.41, Krusell et al. (2000) is 1.66, by Ciccone and Peri (2005) is 1.50, by Autor et al. (2008) is 1.57.

panel of Figure 3.[16] We note that the slope of the relative labor demand curve falls as we move from left to right along the horizontal axis. Therefore, we can infer that the relative male-female labor demand curve is not a downward sloping straight line but instead is a convex curve through the origin. This also supports the Table 2 model specification test results, which suggest that the CES specification is not the most appropriate framework for our sample data.

Goldin (2014) shows that the gender pay gap has narrowed within almost all age groups over the past several decades. Consistent with this finding, Figure 4 shows that the relative female/male wage ratio falls more in the relatively older age group than it does in the younger cohort. As shown, the younger group has a more volatile labor supply ratio than the relatively older group, possibly because this age range includes childbearing years.[17] A large existing literature including Hotz et al. (1997), Buckles (2008), Cristia (2008), Miller (2011), Bratti and Cavalli (2014) and Herr (2016), among others, has already established that labor market disruption due to motherhood has a significant negative impact on labor market outcomes.

Table 5 shows the heterogeneous impacts of the relative female labor supply on the relative wage ratios.[18] The left and right panel show the results for relatively younger and older age groups, respectively. In both the panels, we use three model specifications, which are same as columns 3 to 5 in Table 3. As shown, the elasticity of substitution parameter is close to 4 for the younger group, and it varies between 0.75 and 1.21 for the relatively older group. These results imply that a 1% increase in the relative female labor supply decreases the male-female wage ratios by approximately 4 times more for older group than for the younger group.

[16] All these values are reported in Table 4. These values are the average male-female labor supply ratios of each state for the period 1980-2014.

[17] We form two groups based on the prime age for timing of motherhood.

[18] The derivation of the marginal rate of technical substitution for the VES specification is shown in the Appendix.

4.3 Robustness Check

We have discussed how Bartik instruments can potentially fail the exogeneity condition because each state's industry composition can be correlated with the unobserved local labor market conditions. To address this potential concern, we follow an approach similar to that of Autor et al. (2013) and use a 5-year lag of industry employment shares to avoid any kind of potential contemporary correlation between the error term and the industry composition.[19] As shown in Appendix Table 3, the 2SLS estimate of σ from our most robust model specification is 1.59, which is very close to our baseline estimate 1.72. Thus, the Appendix Table 3 results suggest that our 2SLS estimates are possibly not driven by any spurious correlation between a state's unobserved labor market conditions and industry composition.

Another potential concern regarding the validity of our instruments is whether state political economic conditions affect both relative female labor supply and the industry component because state politicians may introduce different state policies to encourage a higher labor force participation rate depending on the labor market conditions. To address this concern, we include state fixed effects that absorb the time-invariant state political economy effects and, in addition, we use three state political variables, and the results are shown in Appendix Table 5. As shown, our elasticity substitution parameter estimates vary between 1.49 and 1.98, suggesting that it is likely our results are not driven by any state-level political economy effects.

Having established the robustness of the validity of our instrument, we devote the remainder of this section to the choice of production function and different model specifications. By estimating the Box-Cox transformation parameter (λ) on both dependent and independent variables, we show that λ is closer to 1 than 0; hence, we have used the VES production function. To check whether our 2SLS estimates from the VES specification are sensitive to

[19] To estimate the effects of import competition on wage and employment in the US local labor market, Autor et al. (2013) use Bartik instruments to construct regional variation in exposure to trade with China. Specifically, their Bartik instrument consists of the canonical product of commuting zone-specific industry composition and growth in imports to other high-income countries from China. To avoid any kind of anticipation effect, Autor et al. (2013) use a decade lag of commuting zone-specific industry composition.

the choice of production function, we estimate the elasticity of substitution parameter from CES and the translog production functions. The results are shown in Appendix Tables 6 and 7, respectively.

As shown in Appendix Table 6, the 2SLS estimate σ from CES varies between 1.74 and 2.28 when we include state economic controls. This means a 1% increase in the relative female labor supply reduces the male-female wage ratio by approximately 0.43-0.58%. Thus, the CES results are also very close to the baseline estimates we obtain from the VES. Since, like the VES, the translog production function allows the elasticity substitution parameter to vary along the input ratios, we also use the translog production function to check the sensitivity of our baseline estimates. The results are shown in Appendix Table 7. We see that when we include key state economic control variables in columns 4 and 5, the elasticity of substitution parameter lies between 1.48 and 1.64. From an empirical point of view, these estimates are almost identical to our VES estimates. Therefore, our estimated elasticity of substitution parameter most likely does not depend much on the choice of the production function.

Following Katz and Murphy (1992), we use a linear time trend in all model specifications and show that the simple and elegant Katz-Murphy model can explain a large variation in the relative male-female wage ratio. Of course, using a linear time trend is a simplified assumption. In general, states can have different time trends; therefore, to check the robustness of our 2SLS estimates, we also separately allow quadratic time trends and time trends specific to 51 states and 4 regions. All the results are shown in Appendix Table 8. In addition, without following the Katz and Murphy (1992) model specification, we can also use year fixed effects. As shown in Appendix Table 8, the elasticity of substitution parameter varies over the range 1.18 to 2.21 for all 4 different specifications. Therefore, these results suggest that our estimated elasticity substitution parameters are robust across different model specifications.

To summarize, we have performed a number of robustness checks on our baseline estimates, designed to explore the robustness of our 2SLS estimates along a number of dimensions. To examine the validity of our key identifying assumption, we use the alternative specification of instruments to address any correlation between unobserved labor market conditions and industry composition. All these results are reported in the Appendix. The results from these analyses are, in general, quite reassuring.

5 Conclusion

The main contribution of this study is to provide an estimate of the long-run elasticity of substitution between male and female workers for the period 1980-2014 by exploiting the regional variations in industry-level changes in employment induced by national employment growth. In the first stage of the 2SLS method, we show that our instruments can explain large variations in the upward trend of the relative female labor supply, and we also discuss this mechanism. To examine the exogeneity of the instruments, we used an alternative specification proposed by Autor et al. (2013) to construct the instruments. In addition, we perform various robustness checks and report the Sargan-Hansen test results. All these results support the validity of our instruments.

By using the Box-Cox transformation, we find that the relationship between the relative wage and labor supply ratios is linear, and hence we use the VES production function instead of the CES function. The 2SLS point estimate varies between 1.67 and 1.72, and the estimate is robust to a wide range of model specifications. By comparing the VES estimates with the estimates obtained from the translog production function, we find that our estimated elasticity of substitution parameter is not sensitive to the choice of production function. Our preferred 2SLS point estimate 1.72 implies that a 1% increase in the relative female labor supply reduces the male-female wage ratio by approximately 0.58%. Using this estimate, we can infer that the wage gap fell approximately 7% during the period 1980-2014 due to a 12% increase in the relative female labor supply.

References

Acemoglu, D. (1998). Why do new technologies complement skills? directed technical change and wage inequality, *Quarterly Journal of Economics* **113**: 1055–1090.

Acemoglu, D. (2002a). Directed technical change, *Review of Economic Studies* **69**: 781–810.

Acemoglu, D. (2002b). Technology and the labor market, *Journal of Economic Literature* **40**: 7–72.

Acemoglu, D. and Autor, D. (2011). Skills, tasks, and technologies: Implications for employment and earnings, *Handbook of Labor Economics Edited by David Card and Orley Ashenfelter, Chapter 12* **4(B)**: 1043–1171.

Acemoglu, D., Autor, D. and Lyle, D. (2004). Women, war, and wages: The effect of female labor supply on the wage structure at midcentury, *Journal of Political Economy* **112(3)**: 497–551.

Acemoglu, D., Finkelstein, A. and Notowidigdo, M. (2010). Income and health soending: Evidence from oil price shocks, *Review of Economics and Statistics* **95(4)**: 1079–1095.

Albanesi, S. and Olivetti, C. (2009). Home production, market production and the gender wage gap: Incentives and expectations., *Review of Economic Dynamics* **12(1)**: 80–107.

Allen, R. (1956). Mathematical analysis for economists, *London: Macmillan* .

Altonji, J. and Blank, R. (1999). Race and gender in the labor market, *In Handbook of Labor Economics Volume 3c, edited by Orley C. Ashenfelter and David Card* pp. 3143–3259.

Anderson, J. (1977). Labor force age structure changes and relative wages, *Harvard University, unpublished paper* .

Andrews, I., Gentzkow, M. and Shapiro, J. (2017). Measuring the sensitivity of parameter estimates to estimation moments, *Quarterly Journal of Economics* **132(4)**: 1553–1592.

Autor, D. and Dorn, D. (2013). The growth of low-skilled service jobs and the polirization of the us labor market, *American Economic Review* **103(5)**: 1553–1597.

Autor, D., Dorn, D. and Hanson, G. (2013). The china syndrome: Local labor market effects of import competition in the united states, *American Economic Review* **103(6)**: 2121–2168.

Autor, D., Dorn, D. and Katz, L. (2017). The fall of the labor share and the rise of superstar firms, *NBER Working Paper* .

Autor, D. and Duggan, M. (2003). The rise in the disability rolls and the decline in unemployment, *Quarterly Journal of Economics* **118(1)**: 157–205.

Autor, D., Katz, L. and Kearney, M. (2008). Trends in u.s. wage inequality in the 1990s: Revising the revisionists, *Review of Economics and Statistics* **90 (2)**: 300–323.

Autor, D., Katz, L. and Krueger, A. (1998). Computing inequality: Have computers changed the labor market?, *Quarterly Journal of Economics* **113**: 1069–1214.

Bartik, T. (1991). Who benefits from state and local economic development policies?, *W.E. Upjohn Institute* .

Becker, G., Hubbard, W. and Murphy, K. (2010). Explaining the worldwide boom in higher education of women., *Journal of Human Capital* **4(3)**: 203–241.

Berger, M. (1983). Changes in labor force composition and male earnings: A production approach, *Journal of Human Resources* **18**: 177–196.

Berndt, E. and Christensen, L. (1974). Testing for the existence of a consistent aggregate index of labor input, *American Economic Review* **64**: 391–404.

Bertrand, M. (2011). New perspectives on gender, *Handbook of Labor Economics, Volume 4b edited by Orley C. Ashenfelter and David Card* pp. 1545–1592.

Bertrand, M., Chugh, D. and Mullainathan, S. (2005). Implicit discrimination., *American Economic Review* **95(2)**: 94–98.

Black, D. (1995). Discrimination in an equilibrium search model, *Journal of Labor Economics* **13 (2)**: 309–334.

Black, D., Haviland, A., Sanders, S. and Taylor, L. (2008). Gender wage disparities among the highly educated, *Journal of Human Resources* **13(3)**: 630–659.

Blanchard, O. and Katz, L. (1992). Regional evolutions, *Brookings Papers on Economic Activity* .

Blau, F. and Kahn, L. (2006). The u.s. gender pay gap in the 1990s: Slowing convergence, *Industrial and Labor Relations Review* **60(1)**: 4566.

Blau, F. and Kahn, L. (2007). Changes in the labor supply behavior of married women: 19802000, *Journal of Labor Economics* **25(3)**: 393–438.

Blau, F. and Kahn, L. (2013). Female labor supply: Why is the us falling behind?, *American Economic Review* **103(3)**: 251–256.

Blau, F. and Kahn, L. (2016). The gender wage gap: Extent, trends, and explanations, *Journal of Economic Literature* **Forthcoming**.

Borghans, L., TerWeel, B. and Weinberg, B. (2014). People skills and the labor-market outcomes of underrepresented groups, *Industrial and Labor Relations Review* **67 (2)**: 287–334.

Borjas, G. (1983). The substitutability of black, hispanic and white labor, *Economic Inquiry* **21(1)**: 93–106.

Borjas, G. (1986). The demographic determinants of the demand for black labor, *Richard B. Freeman and Harry J. Holzer (eds.), Inner City Black Youth Unemployment* .

Bound, J. and Holzer, H. (2000). Demand shifts, population adjustments, and labor market outcomes during the 1980s, *Journal of Labor Economics* **129(1)**: 1–59.

Bratti, M. and Cavalli, L. (2014). Delayed first birth and new mothers labor market outcomes: Evidence from biological fertility shocks, *European Journal of Population* **30(1)**: 35–63.

Buckles, K. (2008). Understanding the returns to delayed childbearing for working women, *American Economic Review* **98(2)**: 403–407.

Christensen, L., Jorgenson, D. and Lau, L. (1973). Transcendental logarithmic production frontiers, *Review of Economic and Statistics* **55**: 28–45.

Ciccone, A. and Peri, G. (2005). Long-run substitutability between more and less educated workers: Evidence from u.s. states, 1950-1990, *Review of Economics and Statistics* **87(4)**: 652–663.

Correll, S., Benard, S. and Paik, I. (2007). Getting a job: Is there a motherhood penalty?, *American Journal of Sociology* **112(5)**: 1297–1338.

Costrell, R., Duguay, G. and Treyz, G. (1986). Labour susbtitution and complementarity among age-sex groups, *Applied Economics* **18**: 777–791.

Cotter, D., Hermsen, J. and Vanneman, R. (2011). The end of the gender revolution? gender role attitudes from 1977 to 2008, *American Journal of Sociology* **117 (4)**: 259–289.

Cristia, J. (2008). The effect of a first child on female labor supply: Evidence from women seeking fertility services, *Journal of Human Resources* **43(3)**: 487–510.

Currie, J. and Gruber, J. (1996a). Health insurance eligibility, utilization, medical care and child health, *Quarterly Journal of Economics* **111(2)**: 431–466.

Currie, J. and Gruber, J. (1996b). Saving babies: The efficacy and cost of recent changes in the medicaid eligibilty of pregnant women, *Journal of Political Economy* **104(6)**: 1263–1296.

Dao, M., Das, M., Zsoka, K. and Lian, W. (2017). Why is labor receiving a smaller share of global income? theory and empirical evidence, *Handbook of Labor Economics Edited by David Card and Orley Ashenfelter, Chapter 12* .

Diewert, E. (1971). An application of the shephard duality theorem: A generalized leontief production function, *Journal of Political Economy* **79**: 481–507.

Elsby, M., Hobijn, B. and Sahin, A. (2013). Industry structure, market rivalry and public policy, *Brookings Papers on Economic Activity* pp. 1–42.

Fortin, N. (2015). Gender role attitudes and women's labor market participation: Opting out, aids, and the persistent appeal of housewifery, *Annals of Economics and Statistics* **117/118**: 379–401.

Freeman, B. (1979). The effect of demographic factors on age-earnings profiles, *Journal of Human Resources* **14**: 289–318.

Giorgi, G., Paccagnella, M. and Pellizzari, M. (2015). Gender complementarities in the labor market, *Book Series: Research in Labor Economics edited by Solomon W. Polachek , Konstantinos Tatsiramos , Klaus F. Zimmermann* **41**.

Goldin, C. (2006). The quiet revolution that transformed women's employment, education, and family, *The American Economic Review* **96 (2)**: 1–21.

Goldin, C. (2014). A grand convergence: Its last chapter, *American Economic Review* **104(4)**: 1091–1119.

Goldin, C., Katz, L. and Kuziemko (2006). The homecoming of american college women: The reversal of the college gender gap, *Journal of Economic Perspectives* **20(4)**: 133–156.

Goldin, C., Katz, L. and Kuziemko (2008). The race between education and technology, *Cambridge, MA: Belknap Press* .

Goldsmith-Pinkham, P., Sorkin, I. and Swift, H. (2018). Bartik instruments: What, when, why, and how, *NBER Working Paper No 24408* .

Gould, E., Weinberg, B. and Mustard, D. (2002). Crime rates and local labor market opportunities in the united states 1977-1997, *Review of Economics and Statistics* **84(1)**: 45–61.

Grant, J. (1979). Substitution among labor, labor and cap- ital in u.s. manufacturing, *Michigan State University, unpublished Ph.D. dissertation* .

Grant, J. and Hamermesh, D. (1979). Econometric studies of labor-labor substitution and their implications for policy, *Journal of Human Resources* **14**: 518–542.

Grant, J. and Hamermesh, D. (1981). Labor market competition among youths, white women and others, *Journal of Human Resources* **63(3)**: 354–360.

Hamermesh, D. (1984). Labor substitution, unemployment and wages-with reference to youths and women, *Mimeograph, Michigan State University* .

Hamermesh, D. (1986). The demand for labor in the long run, *0. Ashenfelter and R. Layard (ed.), Handbook of Labor Economics* .

Hamermesh, D. (1993). Labor demand, *Princeton Univeristy Press* .

Herr, J. (2016). Measuring the effect of the timing of first birth, *Journal of Population Economics* **29(1)**: 39–72.

Hicks, J. (1948). The theory of wages, *New York: P. Smith* .

Hotz, V., Mullim, C. and Sanders, S. (1997). Bounding causal effects using data from a contaminated natural experiment: Analysing the effects of teenage childbearing, *The Review of Economic Studies* **64(4)**: 575–603.

Johnson, G. (1970). The demand for labor by educational category, *Southern Economic Journal* **37**: 190–203.

Juhn, C. and Murphy, K. (1997). Wage inequality and family labor supply, *Journal of Labor Economics* **15(1)**: 72–97.

Katz, L. and Murphy, K. (1992). Changes in relative wages, 1963-87: Supply and demand factors, *Quarterly Journal of Economics* **107 (2)**: 35–78.

Kaufman, R. (2010). Race, gender, and the labor market: Inequalities at work, *Lynne Reinner Publishers* pp. 1–277.

Krusell, P., Ohanian, P., Rios-Rull, V. and Violante, G. (2000). Capital-skill complementarity and inequality: A macroeconomic analysis, *Econometrica* **68**: 1029–1053.

Levanon, A., England, P. and Allison, P. (2009). Occupational feminization and pay: Assessing causal dynamics using 1950-2000 u.s. census data, *Social Forces* **88(2)**: 865–981.

Lovell, K. (1973). Ces and ves production functions in a cross-section context, *Journal of Political Economy* **81(3)**: 705–720.

Miller, A. (2011). The effects of motherhood timing on career path, *Journal of Population Economics* **24(3)**: 1071–1100.

Mulligan, C. and Rubinstein, Y. (2008). Selection, investment, and women's relative wages, *Quarterly Journal of Economics* **123(3)**: 1061–1110.

Pollak, R., Sickles, R. and Wales, T. (1984). The ces-translog: Specification and estimation of a new cost function, *Review of Economic and Statistics* **66**: 602–607.

Revankar, N. (1971). A class of variable elasticity of substitution production functions, *Econometrica* **39(1)**: 61–71.

Rosen, S. (1986). The theory of equalizing differences, *In The Handbook of Labor Economics, Vol. 1, edited by Orley Ashenfelter and Richard Layard* .

Rotemberg, J. (1983). Instrumental variable estimation of misspecified models, *MIT Sloan Working Paper* pp. 1508–1583.

Welch, F. and Cunningham, J. (1978). Effects of minimum wages on the level and age composition of youth employment, *Review of Economics and Statistics* **60**: 140–145.

Zarembka, P. (1968). Functional form in the demand for money, *Journal of American Statistical Association* **63**: 502–511.

Appendix

Note that the production function in equation (5) can be written as

$$log\big(Q_{st}\big) = \alpha(1-\delta\rho)\log\big(N_{mst}\big) + \alpha\delta\rho\log\Big[N_{fst} + (\rho-1)N_{mst}\Big] \tag{14}$$

To find out the marginal product of female and male, we take derivative of equation (14) with respect to N_{fst} and N_{mst} and hence we get,

$$\begin{aligned} &\frac{1}{Q_{st}} \times \frac{\partial Q_{st}}{\partial N_{fst}} = \alpha\delta\rho\left(\frac{1}{N_{fst}+(\rho-1)N_{mst}}\right) \\ &\Rightarrow \frac{\partial Q_{st}}{\partial N_{fst}} = \alpha\delta\rho\left(\frac{Q_{st}}{N_{fst}+(\rho-1)N_{mst}}\right) \\ &\Rightarrow MPL_f = \alpha\delta\rho\left(\frac{Q_{st}}{N_{fst}+(\rho-1)N_{mst}}\right) \end{aligned} \tag{15}$$

where MPL_f denotes the marginal product of labor for female. Similarly, we get the marginal product of labor for men,

$$
\begin{aligned}
&\frac{1}{Q_{st}} \times \frac{\partial Q_{st}}{\partial N_{mst}} = \frac{\alpha(1-\delta\rho)}{N_{mst}} + \frac{\alpha\delta\rho}{N_{fst} + (\rho-1)N_{mst}} \times (\rho - 1) \\
&\Rightarrow \frac{\partial Q_{st}}{\partial N_{mst}} = \alpha(1-\delta\rho)\left(\frac{Q_{st}}{N_{mst}}\right) + \Big(\alpha\delta\rho(\rho-1)\Big)\left(\frac{Q_{st}}{N_{fst} + (\rho-1)N_{mst}}\right) \\
&\Rightarrow MPL_m = \alpha(1-\delta\rho)\left(\frac{Q_{st}}{N_{mst}}\right) + \Big(\alpha\delta\rho(\rho-1)\Big)\left(\frac{Q_{st}}{N_{fst} + (\rho-1)N_{mst}}\right) \qquad (16)
\end{aligned}
$$

The Marginal Rate of Technical Substitution (MRTS) of men for women is given by

$$
\begin{aligned}
MRTS &= -\left(\frac{\partial Q_{st}/\partial N_{mst}}{\partial Q_{st}/\partial N_{fst}}\right) \\
&= -\left(\frac{\alpha(1-\delta\rho)\left(\frac{Q_{st}}{N_{mst}}\right) + \Big(\alpha\delta\rho(\rho-1)\Big)\left(\frac{Q_{st}}{N_{fst}+(\rho-1)N_{mst}}\right)}{\alpha\delta\rho\left(\frac{Q_{st}}{N_{fst}+(\rho-1)N_{mst}}\right)}\right) \\
&= -\left[\left(\frac{1-\delta\rho}{\delta\rho}\right)\left(\frac{N_{fst}+(\rho-1)N_{mst}}{N_{mst}}\right) + (\rho-1)\right] \\
&= -\left[\left(\frac{1-\delta\rho}{\delta\rho}\right)\left(\frac{N_{fst}}{N_{mst}}\right) + \left(\frac{1-\delta\rho}{\delta\rho}\right)(\rho-1) + (\rho-1)\right] \\
&= -\left[\left(\frac{1-\delta\rho}{\delta\rho}\right)\left(\frac{N_{fst}}{N_{mst}}\right) + (\rho-1)\left\{\left(\frac{1-\delta\rho}{\delta\rho}\right) + 1\right\}\right] \\
&= -\left[\left(\frac{1-\delta\rho}{\delta\rho}\right)\left(\frac{N_{fst}}{N_{mst}}\right) + (\rho-1)\left\{\frac{1-\delta\rho+\delta\rho}{\delta\rho}\right\}\right] \\
&= -\left[\left(\frac{1-\delta\rho}{\delta\rho}\right)\left(\frac{N_{fst}}{N_{mst}}\right) + \left(\frac{\rho-1}{\delta\rho}\right)\right] \qquad (17)
\end{aligned}
$$

Under the assumption that male and female workers are paid their marginal products, we set the MRTS from equation (17) equal to wage ratios of male and female workers. Thus, the relationship between the marginal products of labor and the wage ratio in year t for state s is given by,

$$
\begin{aligned}
\frac{\mathrm{w}_{mst}}{\mathrm{w}_{fst}} &= \left(\frac{\rho-1}{\delta\rho}\right) + \left(\frac{1-\delta\rho}{\delta\rho}\right)\left(\frac{N_{fst}}{N_{mst}}\right) \\
&= \beta_0 + \beta_1\left(\frac{N_{fst}}{N_{mst}}\right) \qquad (18)
\end{aligned}
$$

where $\beta_0 = (\rho-1)/(\delta\rho)$ and $\beta_1 = (1-\delta\rho)/(\delta\rho)$ and w_{mst} and w_{fst} denote the wage rates for male and female workers. Thus we get,

$$\sigma = 1 + \left(\frac{\beta_0}{\beta_1}\right)\left(\frac{N_{mst}}{N_{fst}}\right) \tag{19}$$

From equation (17) we also note that

$$\begin{aligned} \frac{\partial(MPL_m/MPL_f)}{\partial(N_{mst}/N_{fst})} &= \frac{\partial}{\partial\left(N_{mst}/N_{fst}\right)}\left[\left(\frac{1-\delta\rho}{\delta\rho}\right)\left(\frac{N_{fst}}{N_{mst}}\right) + \left(\frac{\rho-1}{\delta\rho}\right)\right] \\ &= -\left[\left(\frac{1-\delta\rho}{\delta\rho}\right) / \left(\frac{N_{fst}}{N_{mst}}\right)^2\right] \leq 0 \end{aligned} \tag{20}$$

Therefore, isoquant curves must be downward slopping and convex through the origin since $0 < \delta\rho < 1$. Furthermore, we can also show that σ and ρ are positively associated:

$$\begin{aligned} \frac{\partial\sigma}{\partial\rho} &= \frac{\partial}{\partial\rho}\Big[1 + \left(\frac{\rho-1}{1-\delta\rho}\right)\frac{N_{mst}}{N_{fst}}\Big] \\ &= \left(\frac{(1-\delta)}{(1-\delta\rho)^2}\right)\left(\frac{N_{mst}}{N_{fst}}\right) > 0 \end{aligned} \tag{21}$$

VES Production Function for Heterogeneous Inputs

Note that the production function in equation (5) can be written as

$$log\big(Q_{st}\big) = \alpha(1-\delta\rho)\log\left(\sum_{i=1}^{I}\theta_i^{mst}N_{ist}^m\right) + \alpha\delta\rho\log\left[\sum_{j=1}^{J}\theta_j^f N_{jst}^f + (\rho-1)\sum_{i=1}^{I}\theta_i^m N_{ist}^m\right] \tag{22}$$

where we have I and J groups of heterogenous male and female workers and θ_i and θ_j are the share of those groups.

To find out the marginal product of female and male for a specific group, we take derivative of equation (22) with respect to N_{ist}^f and N_{ist}^m and hence we get,

$$\frac{1}{Q_{st}} \times \frac{\partial Q_{st}}{\partial N_{jst}^f} = \alpha\delta\rho\left(\frac{\theta_j^f}{\sum\limits_{j=1}^{J}\theta_j^f N_{jst}^f + (\rho-1)\sum\limits_{i=1}^{I}\theta_i^m N_{ist}^m}\right)$$

$$\Rightarrow \frac{\partial Q_{st}}{\partial N_{jst}^f} = \alpha\delta\rho\left(\frac{Q_{st} \times \theta_j^f}{\sum\limits_{j=1}^{J}\theta_j^f N_{jst}^f + (\rho-1)\sum\limits_{i=1}^{I}\theta_i^m N_{ist}^m}\right)$$

$$\Rightarrow MPL_j^f = \alpha\delta\rho\left(\frac{Q_{st} \times \theta_j^f}{\sum\limits_{j=1}^{J}\theta_j^f N_{jst}^f + (\rho-1)\sum\limits_{i=1}^{I}\theta_i^m N_{ist}^m}\right) \tag{23}$$

where MPL_j^f denotes the marginal product of labor for j-th group of women. Similarly, we get the marginal product of labor for the i-th group of men,

$$\frac{1}{Q_{st}} \times \frac{\partial Q_{st}}{\partial N_{ist}^m} = \frac{\alpha(1-\delta\rho) \times \theta_i^m}{N_{ist}^m} + \frac{\alpha\delta\rho}{\sum\limits_{j=1}^{J}\theta_j^f N_{jst}^f + (\rho-1)\sum\limits_{i=1}^{I}\theta_i^m N_{ist}^m} \times (\rho-1) \times \theta_i^m$$

$$\Rightarrow \frac{\partial Q_{st}}{\partial N_{ist}^m} = \alpha(1-\delta\rho)\left(\frac{Q_{st} \times \theta_i^m}{N_{ist}^m}\right) + \Big(\alpha\delta\rho(\rho-1)\Big)\left(\frac{Q_{st} \times \theta_i^m}{\sum\limits_{j=1}^{J}\theta_j^f N_{jst}^f + (\rho-1)\sum\limits_{i=1}^{I}\theta_i^m N_{ist}^m}\right)$$

$$\Rightarrow MPL_m = \alpha(1-\delta\rho)\left(\frac{Q_{st} \times \theta_i^m}{N_{ist}^m}\right) + \Big(\alpha\delta\rho(\rho-1)\Big)\left(\frac{Q_{st} \times \theta_i^m}{\sum\limits_{j=1}^{J}\theta_j^f N_{jst}^f + (\rho-1)\sum\limits_{i=1}^{I}\theta_i^m N_{ist}^m}\right) \tag{24}$$

The Marginal Rate of Technical Substitution (MRTS) between the i-th group of men and j-th group of women is given by

$$MRTS_{ij} = \frac{\alpha(1-\delta\rho)\left(\frac{Q_{st}\times\theta_i^m}{N_{ist}^m}\right) + \left(\alpha\delta\rho(\rho-1)\right)\left(\frac{Q_{st}\times\theta_i^m}{\sum_{j=1}^{J}\theta_j^f N_{jst}^f + (\rho-1)\sum_{i=1}^{I}\theta_i^m N_{ist}^m}\right)}{\alpha\delta\rho\left(\frac{Q_{st}\times\theta_j^f}{\sum_{j=1}^{J}\theta_j^f N_{jst}^f + (\rho-1)\sum_{i=1}^{I}\theta_i^m N_{ist}^m}\right)} \tag{25}$$

After simplifying the equation (25) one can show that

$$MRTS_{ij} = -\left(\left(\frac{\theta_i^m}{\theta_j^f}\right) \times \left[\left(\frac{1-\delta\rho}{\delta\rho}\right)\left(\frac{N_{fst}}{N_{mst}}\right) + \left(\frac{\rho-1}{\delta\rho}\right)\right]\right) \tag{26}$$

Translog Production Function

The translog production function is

$$ln\big(Q_{st}\big) = a_0 + \sum_i a_i ln(N_{ist}) + \frac{1}{2}\sum_i\sum_j b_{ij} ln(N_{ist}) ln(N_{jst}) \tag{27}$$

where $i, j = \{\text{male, female}\}$ and

$$(i)\ \sum_i a_i = 1; \quad (ii)\ b_{ij} = b_{ji}; \quad (iii)\ \sum_i b_{ij} = 0 \text{ for all } j.$$

The (i) and (iii) equalities results from the assumption that Q_{st} is linear homogenous in the factor inputs. We use the cost minimization and price taking behavior in the labor market to calculate the cost share of the input factors and with some calculation one can show that the cost share equations are linear in the production parameters:

$$s_i = a_i + \sum_j b_{ij} ln(N_{ist}/N_{jst})$$

The elasticity of substitution parameter can be written as

$$\sigma_{ij} = \frac{b_{ij} + s_i s_j}{s_i s_j}.$$

Table 1: Summary Statistics of the State Aggregate Data

		By Time			By Region			
	All	1980-1989	1990-1999	2000-2014	North East	Mid West	South	West
Male/Female Relative Wage	1.674	1.999	1.641	1.480	1.655	1.731	1.636	1.684
	(0.298)	(0.342)	(0.136)	(0.091)	(0.299)	(0.327)	(0.243)	(0.326)
Female/Male Relative Supply	0.908	0.847	0.915	0.943	0.937	0.926	0.920	0.855
	(0.088)	(0.083)	(0.080)	(0.072)	(0.078)	(0.073)	(0.096)	(0.071)
State Control								
Poverty	13.149	13.868	13.158	12.628	10.489	11.893	15.838	12.631
	(3.914)	(4.365)	(4.010)	(3.394)	(2.704)	(2.313)	(4.143)	(3.413)
Unemployment	6.092	7.043	5.410	5.914	5.732	5.562	6.502	6.295
	(2.116)	(2.359)	(1.537)	(2.057)	(1.839)	(2.245)	(2.168)	(1.962)
Minimum Wage	4.856	3.103	4.352	6.362	5.199	4.646	4.773	4.922
	(1.673)	(0.545)	(0.762)	(1.207)	(1.637)	(1.659)	(1.528)	(1.846)
Log Population	14.985	14.863	14.952	15.089	14.970	15.121	15.203	14.585
	(1.031)	(1.018)	(1.027)	(1.034)	(1.173)	(0.936)	(0.881)	(1.078)
Log GDP	11.434	10.732	11.337	11.966	11.467	11.535	11.624	11.070
	(1.158)	(1.025)	(1.046)	(1.041)	(1.386)	(1.085)	(0.956)	(1.211)
Migration	0.028	0.027	0.040	0.021	0.023	0.022	0.029	0.037
	(0.024)	(0.022)	(0.032)	(0.012)	(0.018)	(0.016)	(0.022)	(0.031)
No of Observations	1,785	510	510	765	315	420	595	455

The summary statistics table reports mean and standard deviations (in parentheses) for the March CPS 5 percent outgoing rotation samples of full time workers ages in between 18-65 from 1980 to 2014. To estimate the composition adjusted log wage we regress the annual wage on five eduction categories (high school drop out, high school graduate, some college, college graduate, and post college), four potential experience groups (0-9, 10-19, 20-29, 30 and above), interactions between education and potential experience categories, dummies for 4 regions, married, union, metro area, log weeks and hours of work, 7 occupations, 14 industries, black and other non white races. Annual earnings are deflated by using consumer price index for year 2000.

Table 2: Specification Test for the Selection of Production Function By Using the Box-Cox Transformation

Dependent Variable: Composition Adjusted Male/Female Relative Annual Earnings Ratio

	(1)			(2)		
	Estimate	Lower Bound	Upper Bound	Estimate	Lower Bound	Upper Bound
Box-Cox Transformation	0.943***	0.915	0.971	1.293***	1.191	1.394
Parameter (λ)	(0.014)			(0.052)		
Female/Male	-1.182***	-1.229	-1.135	-0.830***	-1.014	-0.646
Relative Supply	(0.024)			(0.094)		
Constant	2.591***	2.571	2.611	3.110***	2.955	3.264
	(0.010)			(0.079)		
Control Variables	No	No	No	Yes	Yes	Yes
R^2	0.181			0.621		
No of Observations	1,785	1,785	1,785	1,785	1,785	1,785

The reported coefficients are obtained from Non-linear Least Squares. The state level clustered standard errors are shown in the parentheses. The list of the control variables are shown in summary statistics Table 1. The notation $*$ represents the statistical significance levels: $*p < 0.10$, $**\ p < 0.05$ and $***p < 0.01$.

Table 3: Elasticity of Substitutions Between Men and Women from the VES Production Function, 1980-2014

Dependent Variable: Composition Adjusted Male/Female Relative Annual Earnings Ratio

	(1)		(2)		(3)		(4)		(5)	
	OLS	2SLS	OLS	2SLS	OLS	2SLS	OLS	2SLS	OLS	2SLS
Female/Male Lab Supply	-2.282***	-5.149***	-0.497***	-3.314***	-0.348***	-1.480***	-0.338***	-1.158***	-0.335***	-1.171***
	(0.200)	(0.271)	(0.158)	(0.450)	(0.083)	(0.231)	(0.103)	(0.250)	(0.094)	(0.239)
Time			-0.020***	-0.008***	-0.016***	-0.012***	-0.007***	-0.002	-0.009***	-0.002
			(0.001)	(0.002)	(0.001)	(0.001)	(0.002)	(0.002)	(0.003)	(0.002)
Poverty					0.004*	0.005***			0.003	0.004**
					(0.002)	(0.002)			(0.002)	(0.002)
Unemployment					0.013***	0.006***			0.003	-0.000
					(0.002)	(0.002)			(0.004)	(0.002)
Minimum Wage							0.032***	0.025***	0.027***	0.023***
							(0.006)	(0.005)	(0.006)	(0.005)
Log Population							0.294**	0.138*	0.230*	0.110
							(0.117)	(0.075)	(0.134)	(0.071)
Log GDP							-0.323***	-0.297***	-0.266***	-0.278***
							(0.053)	(0.033)	(0.075)	(0.038)
Migration							0.021	0.224	0.023	0.223
							(0.136)	(0.153)	(0.137)	(0.153)
State FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Demographic Controls	No	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
Constant	3.853***	7.082***	2.749***	5.229***	1.277***	1.914***	0.482	2.806***	0.631	2.896***
	(0.164)	(0.304)	(0.127)	(0.461)	(0.124)	(0.169)	(1.241)	(0.941)	(1.267)	(0.906)
Elasticity of Substitution	0.859	0.514	5.083	0.737	3.041	0.424	0.570	1.669	1.072	1.724
Sargan Test Stat		31.117		36.986		25.739		17.899		13.517
(p-value)		(0.000)		(0.000)		(0.018)		(0.161)		(0.409)
First Stage Fstat		67.92		28.81		23.75		19.34		24.21
Adjusted R^2	0.402	0.010	0.701	0.453	0.812	0.755	0.825	0.801	0.824	0.799
Observations	1,785	1,778	1,785	1,778	1,596	1,589	1,647	1,640	1,596	1,589

The state level clustered standard errors are reported in the parentheses. The elasticity of substitution is calculated by using expression: $[1+(\beta_0/\beta_1)\times(N_{mst}/N_{fst}) = (\beta_0/\beta_1)\times 1.101]$. The Sargan Test Statistics test statistics is defined as nR_e^2 where n is the number of observations and R_e^2 is obtain from the second state error regression. The test statistics follows χ_r^2 where r is the number of over-identifying restriction. The notation $*$ represents the statistical significance levels: $*p < 0.10$, $**\ p < 0.05$ and $***p < 0.01$.

Table 4: Relative Male-Female Labor Supply Ratios (N_m/N_f) and VES Estimated Elasticity of Substitution ($\hat{\sigma}$) by State

State	N_m/N_f	$\hat{\sigma}$	$1/\hat{\sigma}$	State	N_m/N_f	$\hat{\sigma}$	$1/\hat{\sigma}$
Alabama	1.117	1.759	0.568	Montana	1.074	1.654	0.605
Alaska	1.137	1.808	0.553	Nebraska	1.068	1.639	0.610
Arizona	1.236	2.052	0.487	Nevada	1.210	1.989	0.503
Arkansas	1.105	1.730	0.578	New Hampshire	1.103	1.725	0.580
California	1.217	2.006	0.498	New Jersey	1.134	1.800	0.556
Colorado	1.190	1.939	0.516	New Mexico	1.150	1.840	0.543
Connecticut	1.053	1.600	0.625	New York	1.094	1.702	0.588
Delaware	1.077	1.660	0.602	North Carolina	1.083	1.675	0.597
District of Columbia	0.902	1.227	0.815	North Dakota	1.015	1.508	0.663
Florida	1.101	1.720	0.581	Ohio	1.110	1.742	0.574
Georgia	1.079	1.665	0.601	Oklahoma	1.151	1.844	0.542
Hawaii	1.071	1.646	0.608	Oregon	1.159	1.863	0.537
Idaho	1.184	1.925	0.519	Pennsylvania	1.115	1.753	0.570
Illinois	1.136	1.806	0.554	Rhode Island	1.041	1.572	0.636
Indiana	1.135	1.804	0.554	South Carolina	1.054	1.603	0.624
Iowa	1.072	1.647	0.607	South Dakota	1.032	1.548	0.646
Kansas	1.125	1.780	0.562	Tennessee	1.098	1.713	0.584
Kentucky	1.119	1.764	0.567	Texas	1.217	2.007	0.498
Louisiana	1.131	1.794	0.557	Utah	1.293	2.194	0.456
Maine	1.059	1.616	0.619	Vermont	1.028	1.539	0.650
Maryland	1.062	1.623	0.616	Virginia	1.117	1.759	0.569
Massachusetts	1.048	1.590	0.629	Washington	1.168	1.884	0.531
Michigan	1.122	1.770	0.565	West Virginia	1.208	1.984	0.504
Minnesota	1.066	1.633	0.613	Wisconsin	1.077	1.660	0.602
Mississippi	1.068	1.637	0.611	Wyoming	1.228	2.032	0.492
Missouri	1.082	1.673	0.598				

We use the expression, $\hat{\sigma} = 1 + \left(\hat{\beta}_0/\hat{\beta}_1\right)\left(N_m/N_f\right)$ to obtain the VES elasticity of substitution ($\hat{\sigma}$) parameter for each state where $\hat{\beta}_0$ and $\hat{\beta}_1$ are the 2SLS estimated coefficients from equation (9) and N_m/N_f is the average male-female labor supply ratio for each state for the period 1980-2014.

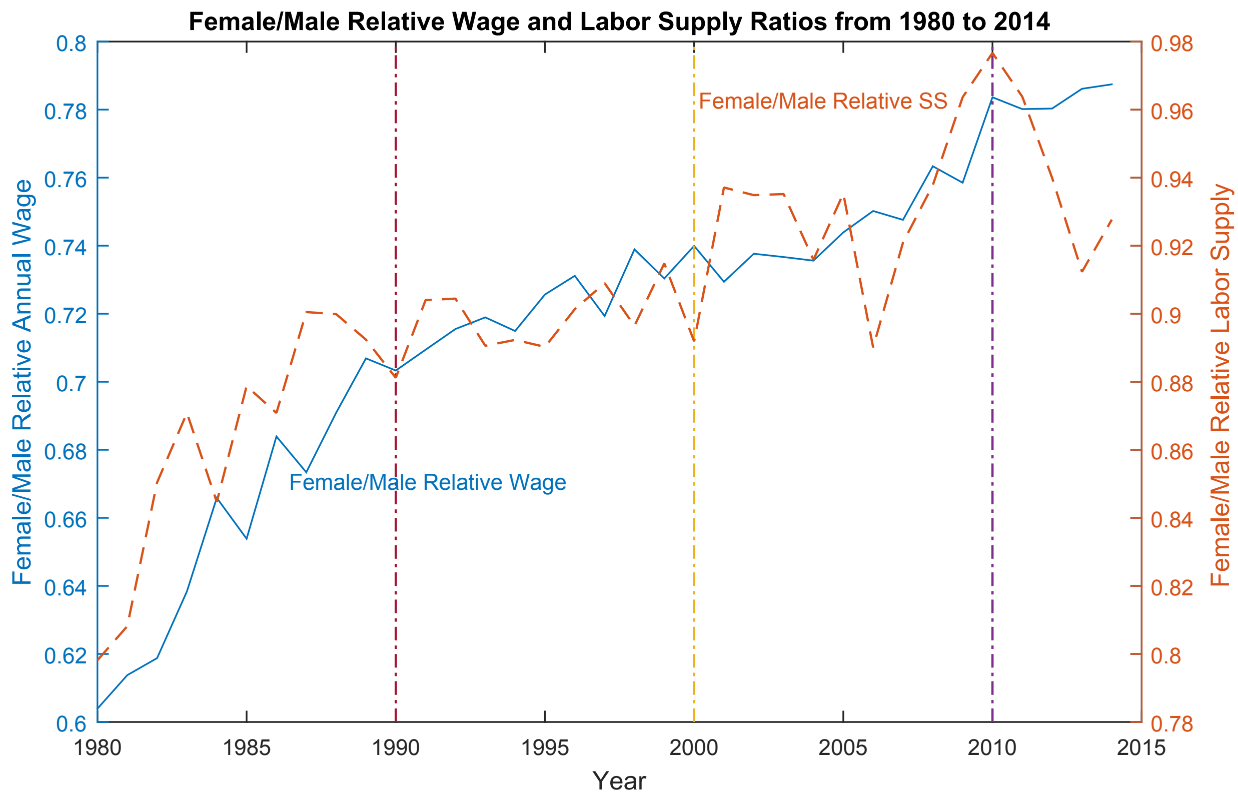
Table 5: Elasticity of Substitutions Between Relatively Younger (Age 18-35) and Older (Age 36-65) Men and Women

Dependent Variable: Composition Adjusted Male/Female Relative Annual Earnings Ratio

	Age Group: 18-35			Age Group: 36-65		
	(1)	(2)	(3)	(1)	(2)	(3)
Female/Male Relative	-1.366***	-1.286***	-1.241***	-1.113***	-0.913***	-0.779***
Labor Supply	(0.361)	(0.379)	(0.375)	(0.232)	(0.268)	(0.233)
Time	-0.010***	0.004	0.005	-0.012***	-0.005**	-0.004
	(0.001)	(0.004)	(0.004)	(0.001)	(0.002)	(0.003)
Poverty	0.001		0.001	0.000		-0.000
	(0.003)		(0.003)	(0.002)		(0.002)
Unemployment	0.009***		0.000	0.005		-0.002
	(0.003)		(0.004)	(0.004)		(0.003)
Minimum Wage		0.026***	0.023***		0.025***	0.029***
		(0.008)	(0.009)		(0.008)	(0.007)
Log Population		-0.068	-0.073		0.161	0.244***
		(0.123)	(0.134)		(0.108)	(0.093)
Log GDP		-0.318***	-0.323***		-0.237***	-0.295***
		(0.052)	(0.063)		(0.057)	(0.054)
Migration		0.059	0.043		0.220	0.218
		(0.169)	(0.168)		(0.184)	(0.178)
State Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Demographic Controls	Yes	Yes	Yes	Yes	Yes	Yes
Constant	2.244***	5.848***	5.895***	2.040***	1.836	1.239
	(0.268)	(1.765)	(1.832)	(0.191)	(1.148)	(1.012)
Elasticity of Substitution	0.849	4.122	4.350	1.043	1.242	0.774
Adjusted R^2	0.428	0.477	0.490	0.488	0.572	0.602
No of Observations	1,518	1,568	1,518	1,467	1,515	1,467

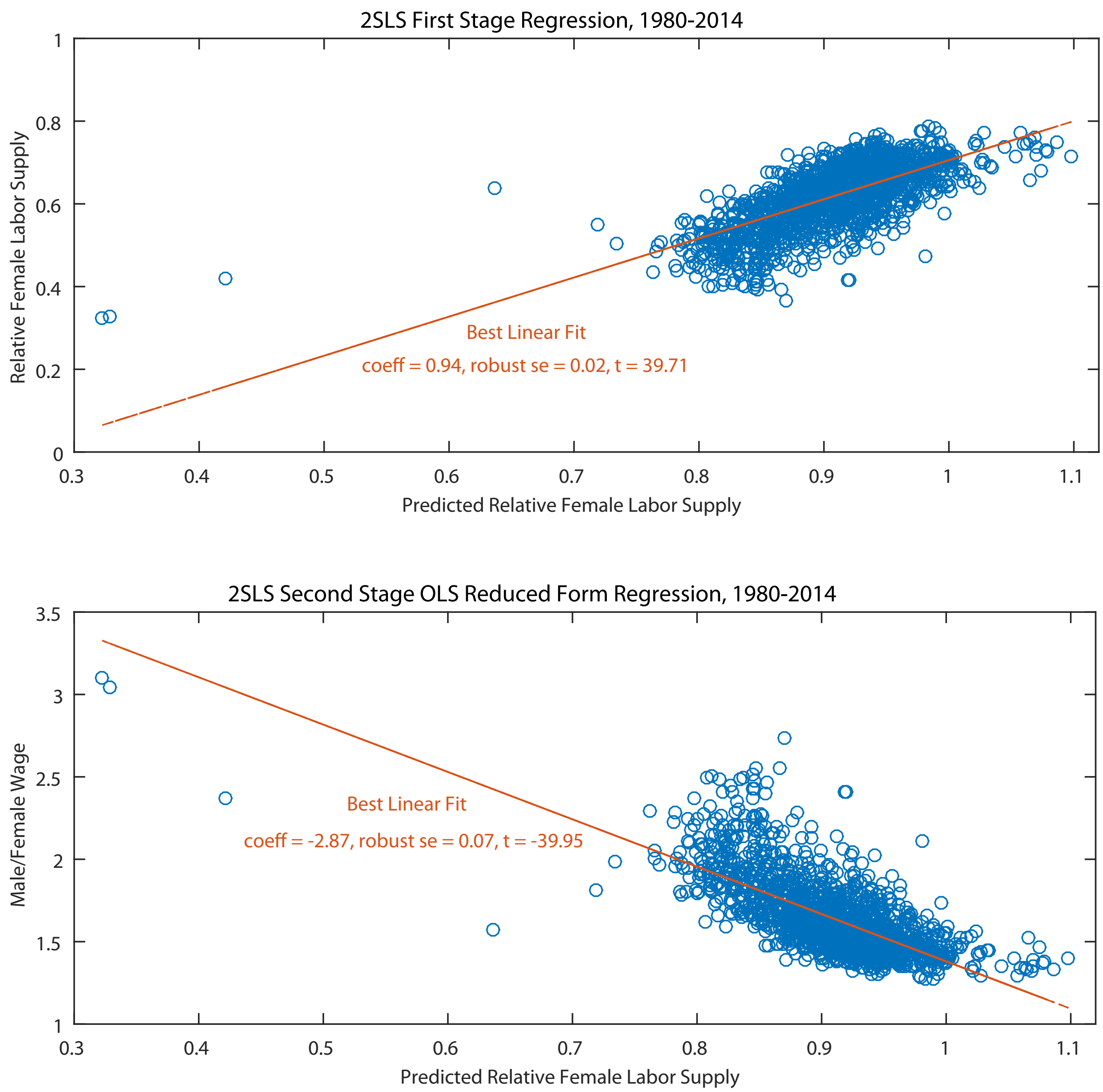
The state level clustered standard errors are reported in the parentheses. The elasticity of substitution is calculated by using expression: $[1 + (\beta_0/\beta_1) \times (N_{mst}/N_{fst})]$, where the ratio N_{mst}/N_{fst} is 1.12 for age group 18-35 and 1.11 for age group 36-65. The notation $*$ represents the statistical significance levels: $*p < 0.10$, $**\ p < 0.05$ and $***p < 0.01$.

Figure 1: Relative Female/Male Annual Wage and Labor Supply Ratios from 1980 - 2014



Female/Male annual wage and labor supply ratios are calculated using the March CPS 5 percent outgoing rotation samples which include full time workers age in between 18-65. The left vertical axis measures female/male relative annual wage ratios and the right vertical axis measures the female-male relative labor supply ratios.

Figure 2: Impact of Relative Female Labor Supply on Relative Wage Ratios: Plots of First Stage and Reduced Form Estimates



The predicted relative female labor supply is obtained by using 14 instruments. Female/Male relative labor supply and Female/Male annual wage ratios are calculated using the March CPS 5 percent outgoing rotation samples include full time workers ages in between 18-65.

Figure 3: Scatter plot of Relative Female/Male Annual Wage and Labor Supply Ratios and the Marginal Effects of Relative Labor Supply on Relative Wage

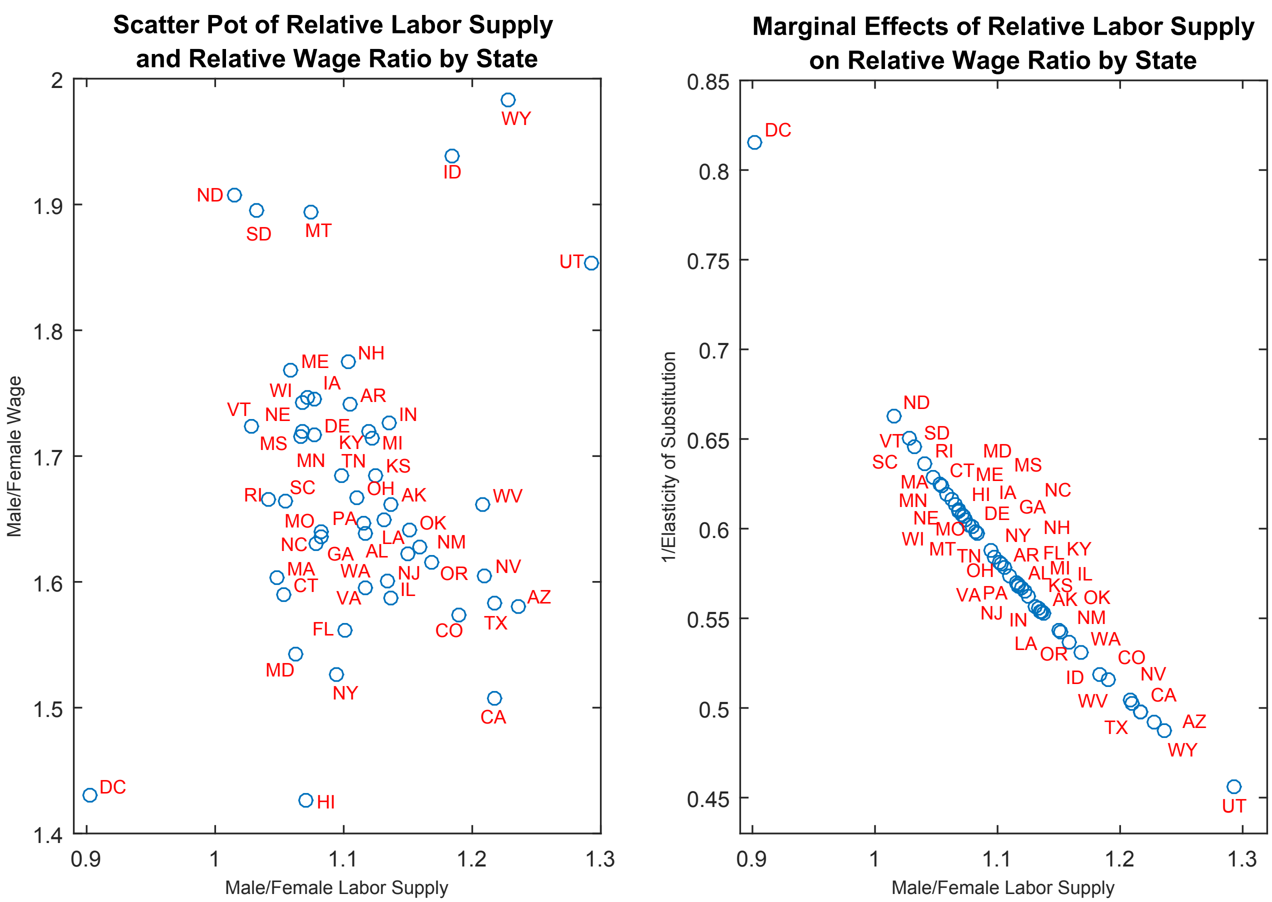
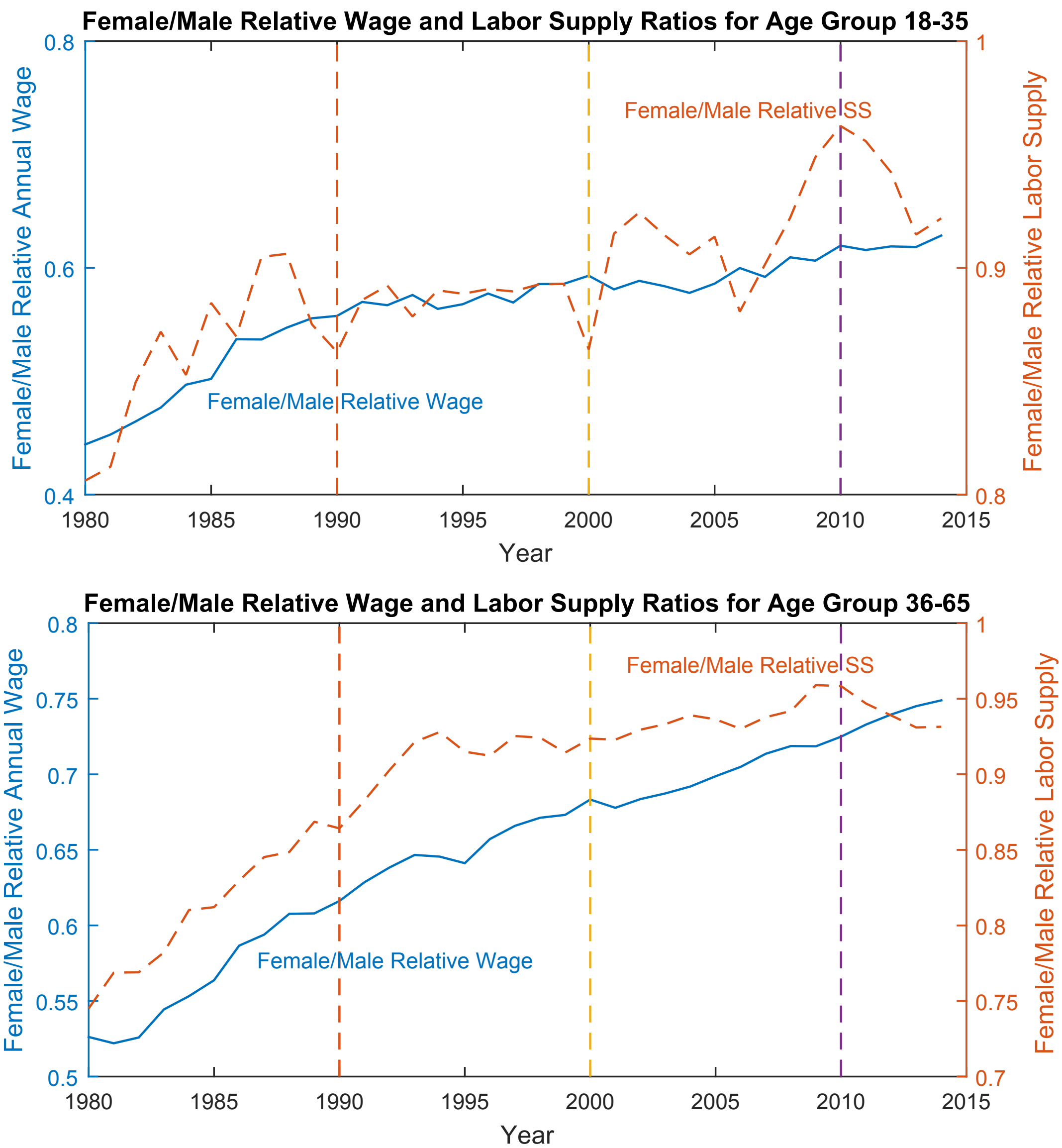


Figure 4: Relative Female/Male Annual Wage and Labor Supply Ratios for Age Groups 18-35 and 36-65



Female/Male annual wage and labor supply ratios are calculated using the March CPS 5 percent outgoing rotation samples which include full time workers. In both the panels, the left vertical axis measures female/male relative annual wage ratios and the right vertical axis measures the female-male relative labor supply ratios.

Table 6: (Appendix Table 1) Summary Statistics of Current Population Survey Data for the Period 1980-2014

	Men	Women	Difference (t-stat)
Education			
HS Dropout	0.021	0.015	0.018
	(0.142)	(0.123)	(18.585)
HS and Some College	0.377	0.436	-0.059
	(0.485)	(0.496)	(-56.977)
College and Post College	0.603	0.549	0.054
	(0.489)	(0.498)	(51.611)
Age			
Age 18 - 35	0.332	0.372	-0.040
	(0.471)	(0.483)	(-39.970)
Age 36 - 45	0.302	0.301	0.001
	(0.459)	(0.459)	(0.970)
Age 45 - 65	0.366	0.327	0.039
	(0.482)	(0.469)	(39.185)
Demographic			
Married	0.745	0.637	0.108
	(0.436)	(0.481)	(110.832)
Union	0.017	0.029	-0.012
	(0.130)	(0.169)	(-38.919)
Metro	0.803	0.783	0.020
	(0.397)	(0.412)	(23.237)
Black	0.052	0.087	-0.035
	(0.221)	(0.281)	(-65.308)
No of Observations	448,395	446,920	1,475

The summary statistics table reports mean and standard deviations (in parentheses) for the March CPS 5 percent outgoing rotation samples of full time workers ages in between 18-65 from 1980 to 2014.

Table 7: (Appendix Table 2) The First Stage of the Two Stage Least Square Regressions

Dependent Variable: Female/Male Labor Supply Ratio

	(1)	(2)	(3)	(4)	(5)
Agriculture, Forestry and Fisheries Industry	1.788*	0.303	0.344	0.348	0.407
	(0.915)	(0.506)	(0.404)	(0.451)	(0.489)
Mining Industry	-1.752	-8.436***	-12.350***	-9.770***	-12.817***
	(1.675)	(2.707)	(2.553)	(2.214)	(2.171)
Construction Industry	2.366**	1.511	0.453	1.261	1.042
	(1.106)	(1.083)	(1.185)	(1.420)	(1.390)
Manufacturing Industry	3.131***	0.625	0.460	-0.051	-0.042
	(0.381)	(0.478)	(0.651)	(0.513)	(0.474)
Transportation, Communication and Other Public Utilities Industry	0.186	-0.403	-2.274*	-0.584	-2.389*
	(1.285)	(1.208)	(1.271)	(1.286)	(1.378)
Wholesale Trade Industry	-1.709**	-0.294	-0.007	0.195	0.392
	(0.736)	(0.593)	(0.649)	(0.672)	(0.633)
Retail Trade Industry	-0.763***	-0.158	0.088	-0.257	-0.084
	(0.231)	(0.207)	(0.211)	(0.224)	(0.225)
Finance, Insurance and Real State Industry	-0.592*	-0.255	-0.743*	-0.212	-0.626*
	(0.302)	(0.400)	(0.393)	(0.344)	(0.355)
Business and Repais Service Industry	-8.652***	2.468	1.960	0.056	-0.575
	(2.776)	(3.580)	(3.561)	(2.492)	(2.205)
Personal Services Industry	-1.165**	-1.119	0.177	-0.172	0.555
	(0.570)	(0.932)	(0.876)	(0.761)	(0.482)
Entertainment and Recreation Services Industry	0.357	3.705	4.601	3.933	3.496
	(1.857)	(2.864)	(2.837)	(2.466)	(2.690)
Professional and Related Services Industry	1.428***	1.284***	1.089***	0.985***	0.814***
	(0.202)	(0.308)	(0.303)	(0.263)	(0.244)
Public Administration Industry	0.301	0.957	0.392	0.306	-0.303
	(0.616)	(0.591)	(0.672)	(0.619)	(0.686)
Active duty military Industry	-0.078	-0.328	-0.272	-0.234	-0.218
	(0.263)	(0.285)	(0.298)	(0.340)	(0.353)
State Control	Yes	Yes	Yes	Yes	Yes
Demographic Control	No	No	Yes	Yes	Yes
Adjusted R^2	0.461	0.256	0.276	0.316	0.347
No of Observations	1,778	1,778	1,651	1,702	1,651

The columns 1 to 5 correspond to the exact model specifications used in Table 3. We do not report the coefficients all state and demographic control variables because of space constraint. Using the CPS two-digit industry code we have 14 industries. Therefore, our Bartik instruments consist of predicted two-digit industry level employment growth in 14 industries.

Table 8: (Appendix Table 3) Robustness Check by Using a decade Lag of Industry Compositions to Construct Bartik Instruments

Dependent Variable: Male/Female Annual Wage Ratio

	(1)	(2)	(3)	(4)	(5)
Female/Male Relative	-3.811***	-0.715*	-0.487*	-0.418	-0.373
Labor Supply	(0.517)	(0.383)	(0.284)	(0.325)	(0.353)
Time		-0.014***	-0.014***	-0.006***	-0.007**
		(0.001)	(0.001)	(0.002)	(0.003)
Poverty			0.002		0.000
			(0.001)		(0.001)
Unemployment			0.009***		0.005**
			(0.002)		(0.002)
Minimum Wage				0.014***	0.010**
				(0.004)	(0.004)
Log Population				0.195***	0.248***
				(0.066)	(0.057)
Log GDP				-0.251***	-0.224***
				(0.029)	(0.043)
Migration				-0.127	-0.040
				(0.126)	(0.119)
State Fixed Effects	Yes	Yes	Yes	Yes	Yes
Demographic Control	No	No	Yes	Yes	Yes
Constant	5.599***	2.477***	1.456***	1.427	0.884
	(0.572)	(0.400)	(0.170)	(0.997)	(1.127)
Elasticity of Substitution	0.601	2.776	2.256	2.723	1.586
Adjusted R^2	0.000	0.694	0.780	0.778	0.763
No of Observations	1,527	1,527	1,396	1,460	1,396

The state level clustered standard errors are reported in the parentheses. The elasticity of substitution is calculated by using expression: $[1 + (\beta_0/\beta_1) \times (N_{mst}/N_{fst}) = (\beta_0/\beta_1) \times 1.09]$. The notation $*$ represents the statistical significance levels: $*p < 0.10$, $**\ p < 0.05$ and $***p < 0.01$.

Table 9: (Appendix Table 4) Summary Statistics of Political and Demographic Variables

	All	North East	Mid West	South	West
Political Variables					
Democratic Governor	0.502	0.486	0.364	0.570	0.558
	(0.500)	(0.501)	(0.482)	(0.496)	(0.497)
No of Democrats in Lower House	61.286	94.400	53.275	72.073	31.864
	(32.865)	(34.049)	(19.708)	(27.641)	(13.428)
No of Democrats in Upper House	21.967	23.063	20.995	26.486	16.470
	(9.585)	(8.662)	(9.481)	(9.443)	(7.212)
Demographic Control					
Male/Female Metro Area	0.999	1.003	1.006	0.994	0.996
	0.044	(0.045)	(0.035)	(0.044)	(0.048)
Male/Female Married	1.135	1.142	1.100	1.171	1.117
	(0.077)	(0.071)	(0.071)	(0.074)	(0.070)
Male/Female Black	0.936	0.985	0.979	0.772	1.098
	(0.661)	(0.764)	(0.895)	(0.159)	(0.712)
No of Observations	1,785	315	420	595	455

The summary statistics table reports mean and standard deviations (in parentheses) for the March CPS 5 percent outgoing rotation samples of full time workers ages in between 18-65 from 1980 to 2014.

Table 10: (Appendix Table 5) Robustness Check for Different Political Variables

Dependent Variable: Male/Female Annual Wage Ratio

	(1)	(2)	(3)	(4)
Female/Male Relative	-1.075***	-1.098***	-1.086***	-1.081***
Labor Supply	(0.239)	(0.243)	(0.242)	(0.242)
Democratic Governor	0.001			-0.002
	(0.006)			(0.006)
No of Democrats in Lower House		0.001**		0.000
		(0.000)		(0.000)
No of Democrats in Upper House			0.002***	0.001
			(0.001)	(0.001)
State Economic Control	Yes	Yes	Yes	Yes
Time Trend and State FE	Yes	Yes	Yes	Yes
Demographic Control	Yes	Yes	Yes	Yes
Constant	2.431**	2.966**	2.670***	2.763***
	(0.979)	(1.243)	(1.005)	(0.996)
Elasticity of Substitution	1.488	1.975	1.706	1.814
Sargan Test Statistics	16.971	12.064	12.607	12.580
(p-value)	(0.201)	(0.522)	(0.479)	(0.481)
Adjusted R^2	0.798	0.799	0.800	0.800
No of Observations	1,561	1,527	1,527	1,527

The state level clustered standard errors are reported in the parentheses. The CES elasticity of substitution is the inverse of the coefficient of log female/male relative labor supply. The demographic controls consist of ratios of male-female metropolitan area, married and black. We do not report these coefficients because of space constraint. The notation $*$ represents the statistical significance levels: $*p < 0.10$, $**\ p < 0.05$ and $***p < 0.01$.

Table 11: (Appendix Table 6) Robustness Check for Elasticity of Substitutions Between Men and Women from the CES Production Function, 1980-2014

Dependent Variable: Composition Adjusted Log Male/Female Relative Annual Earnings Ratio

	(1)		(2)		(3)		(4)		(5)	
	OLS	2SLS	OLS	2SLS	OLS	2SLS	OLS	2SLS	OLS	2SLS
Log Male/Female Relative Supply	1.115***	2.378***	0.188***	1.276***	0.137***	0.572***	0.133**	0.436***	0.133***	0.438***
	(0.085)	(0.121)	(0.063)	(0.175)	(0.040)	(0.100)	(0.050)	(0.112)	(0.045)	(0.105)
Time			-0.011***	-0.006***	-0.010***	-0.008***	-0.005***	-0.003***	-0.006***	-0.003**
			(0.001)	(0.001)	(0.000)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Poverty					0.002	0.002			0.001	0.002
					(0.001)	(0.001)			(0.001)	(0.001)
Unemployment					0.006	0.003			0.002	-0.000
					(0.001)	(0.001)			(0.002)	(0.001)
Minimum Wage							0.015	0.012	0.013	0.011
							(0.004)	(0.003)	(0.003)	(0.003)
Log Population							0.148	0.088	0.117	0.076
							(0.059)	(0.038)	(0.069)	(0.036)
Log GDP							-0.162***	-0.152***	-0.134***	-0.144***
							(0.027)	(0.017)	(0.039)	(0.019)
Migration							0.052	0.136*	0.051	0.132*
							(0.076)	(0.079)	(0.076)	(0.078)
State FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Demographic Controls	No	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
Constant	0.437	0.562	0.83	0.589	0.125	-0.082	-0.330	-0.259	-0.248	0.285
	(0.017)	(0.031)	(0.019)	(0.019)	(0.063)	(0.068)	(0.613)	(0.373)	(0.626)	(0.357)
Elasticity of Substitution	0.897	0.421	5.318	0.784	7.299	1.748	7.519	2.294	7.519	2.283
Sargan Test Stat		36.869		34.636	0.840	22.610		15.957		14.351
(p-value)		(0.000)		(0.001)		(0.047)		(0.252)		(0.350)
First Stage Fstat		62.33		27.82		23.23		17.73		23.16
Adjusted R^2	0.425	0.059	0.771	0.596	0.840	0.803	0.850	0.834	0.848	0.832
Observations	1,785	1,778	1,785	1,778	1,596	1,589	1,647	1,640	1,596	1,589

The state level clustered standard errors are reported in the parentheses. The CES elasticity of substitution is the inverse of the coefficient of log female/male relative labor supply. The demographic controls consist of ratios of male-female metropolitan area, married and black. We do not report these coefficients because of space constraint. The notation $*$ represents the statistical significance levels: $*p < 0.10$, $**\,p < 0.05$ and $***p < 0.01$.

Table 12: (Appendix Table 7) Robustness Check for Elasticity of Substitutions Between Men and Women from the Translog Production Function

	(1)	(2)	(3)	(4)	(5)
Log Female × Male	-3.811***	-0.715*	-0.487*	-0.418	-0.373
Labor Supply	(0.517)	(0.383)	(0.284)	(0.325)	(0.353)
Log Female Labor	0.358	-1.169***	-0.392*	-0.838***	-0.774***
Supply	(0.590)	(0.360)	(0.224)	(0.226)	(0.210)
Log Male Labor	-0.754	1.360***	0.604***	0.942***	0.892***
Supply	(0.625)	(0.385)	(0.230)	(0.233)	(0.217)
Log Female Labor	4.514***	2.333***	0.645*	0.361	0.373
Supply Square	(0.976)	(0.599)	(0.329)	(0.385)	(0.303)
Log Male Labor	4.462***	2.154***	0.589*	0.284	0.300
Supply Square	(0.956)	(0.589)	(0.322)	(0.380)	(0.296)
Time		-0.012***	-0.010***	-0.005***	-0.006***
		(0.000)	(0.000)	(0.001)	(0.001)
Poverty			0.002**		0.002*
			(0.001)		(0.001)
Unemployment			0.004***		-0.001
			(0.001)		(0.001)
Minimum Wage				0.014***	0.013***
				(0.003)	(0.003)
Log Population				0.190***	0.182***
				(0.023)	(0.028)
Log GDP				-0.171***	-0.164***
				(0.015)	(0.020)
Migration				0.076	0.074
				(0.071)	(0.070)
State Fixed Effects	Yes	Yes	Yes	Yes	Yes
Demographic Control	No	No	Yes	Yes	Yes
Constant	2.168***	-0.093	-0.505*	-1.149***	-1.200***
	(0.725)	(0.443)	(0.289)	(0.391)	(0.406)
Elasticity of Substitution	11.567	7.056	1.968	1.486	1.644
Adjusted R^2	0.073	0.665	0.825	0.850	0.847
No of Observations	1,778	1,778	1,589	1,640	1,589

The state level clustered standard errors are reported in the parentheses. The elasticity of substitution is calculated by using the expression shown in the appendix. The notation $*$ represents the statistical significance levels: $*p < 0.10$, $**\,p < 0.05$ and $***p < 0.01$.

Table 13: (Appendix Table 8) Robustness Check for Different Time Trends and Year Fixed Effects

Dependent Variable: Male/Female Annual Wage Ratio

	(1)	(2)	(3)	(4)	(5)
Female/Male Relative	-1.123***	-0.701*	-1.279***	-1.060***	-0.517
Labor Supply	(0.282)	(0.419)	(0.279)	(0.243)	(0.564)
Time Trend		-0.016			
		(0.010)			
Time Trend Square	-0.000	0.000			
	(0.000)	(0.000)			
State-Specific Time Trend			Yes		
Region-Specific Time Trend				Yes	
Year Fixed Effects					Yes
State Economic Control	Yes	Yes	Yes	Yes	Yes
State Fixed Effects	Yes	Yes	Yes	Yes	Yes
Demographic Control	Yes	Yes	Yes	Yes	Yes
Constant	2.758***	1.499	3.413	3.100***	1.026
	(1.000)	(1.346)	(3.604)	(1.084)	(1.638)
Elasticity of Substitution	-1.703	-1.357	-1.938	-2.218	-1.187
Sargan Test Statistics	16.306	17.130	14.728	15.713	10.333
(p-value)	(0.233)	(0.193)	(0.325)	(0.265)	(0.667)
Adjusted R^2	0.794	0.822	0.830	0.802	0.829
No of Observations	1,589	1,589	1,651	1,651	1,651

The state level clustered standard errors are reported in the parentheses. The elasticity of substitution is calculated by using expression: $[1 + (\beta_0/\beta_1) \times (N_{mst}/N_{fst}) = (\beta_0/\beta_1) \times 1.101]$. The Sargan Test Statistics test statistics is defined as nR_e^2 where n is the number of observations and R_e^2 is obtain from the second state error regression. The test statistics follows χ_r^2 where r is the number of over-identifying restriction. The notation $*$ represents the statistical significance levels: $*p < 0.10$, $**\,p < 0.05$ and $***p < 0.01$.