EC339 Applied Macroeconomics Assignment 1

14 November 2024

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Contents:

Abstract:

This paper presents policy recommendations aimed at reducing the gender pay gap in the United Kingdom. By developing and solving a search model with heterogeneous workers—calibrated using empirical UK data—we examine the current state of the labour market to elucidate the origins of wage disparities between men and women. Our labour model and proposed policies are based on the premise that these disparities stem from two exogenous factors: women have lower bargaining power than men, and women face higher search frictions in the labour market. While we suggest policies to address the unequal bargaining power, our main policy focuses on counteracting the effects of higher search frictions by incentivizing firms to hire more women. This is achieved by simultaneously increasing the National Insurance tax on jobs filled by men and decreasing it on jobs filled by women.

1. Introduction, Research Motivation, and Literature

Despite progress since the enactment of equal pay legislation, the gender wage gap remains a persistent issue in the labour market. In 2023, empirical data indicated a mean gender pay gap of 10.7% in the UK (Fawcett 2023). Beyond ethical concerns, this disparity leads to market inefficiencies, such as reduced labour force participation among highly qualified women, which in turn limits the diversity of skills available in the workforce. In the U.S. notably, only one-third of the earnings disparity between men and women who work full-time throughout the year can be attributed to measurable worker characteristics (US Census Bureau 2020). This underscores that unmeasured exogenous factors—such as discrimination and systemic biases—play a significant role, making it an issue that warrants attention from policy-makers.

2. Theoretical Framework : Our Model

We modify the standard Diamond-Mortensen-Pissarides model, including ex-ante heterogeneous workers to distinguish male and female workers. Jobs are kept homogeneous because our model works in random search; firms post the same vacancies for men and women. We assume that both types of workers produce the same output (y), have the same probability of losing their job (λ), and receive the same unemployment benefits (b). Since the main policy we are planning on proposing is implemented through changing the cost distribution of the national insurance tax (T), which is taken on the output of a filled job, we endogenize unemployment benefits (b) to be a function of y and T.

We then denote the following Bellman Equations on the worker side:

$$rW_M = w_M - \lambda(W_M - U_M) \qquad rW_F = w_F - \lambda(W_F - U_F)$$

$$rU_M = b + p_M(W_M - U_M) \qquad rU_F = b + p_F(W_F - U_F)$$

Where: $b = y * T$, w_F and w_M are female and male wages, r is the de-annualised monthly risk-free interest rate, and p_F and p_M are the probabilities for female and male unemployed workers finding a job.

On the firm side, we have ex-ante homogeneous jobs because our model works in random search; firms post the same vacancies for men and women. Which yields the following Bellman Equations:

$$rJ_M = (1 - T_M)y - w_M - \lambda(J_M - V) \qquad rJ_F = (1 - T_F)y - w_F - \lambda(J_F - V)$$

$$rV = -k + q_M(J_M - V) + q_F(J_F - V)$$

Where : $T_M = T_F = T$, k is the cost per month of keeping a vacancy open, and q_F and q_M are the per-period probabilities that a vacancy gets filled by a woman or a man.

Probabilities p_M, p_F, q_M, and q_F are defined by the following matching technology:

$$p_M = \theta^{1-\mu} \quad ; \quad q_M = \theta^{-\mu} \quad ; \quad p_F = \gamma\theta^{1-\mu} \quad ; \quad q_F = \gamma\theta^{-\mu} \, ; \theta = \frac{v}{u_M + u_F}$$

Where θ is labour market tightness, v, u_M, u_F are the respective amounts of: vacancies posted, unemployed men, and unemployed women. μ is the elasticity of the matching function, and finally, γ (< 1) is the parameter we have created to represent the extra search friction that women face compared to men.

Wages are determined through the following Nash Bargaining equations:

$$\frac{W_M - U_M}{\beta_M} = \frac{J_M - V}{(1 - \beta_M)} \qquad \frac{W_F - U_F}{\beta_F} = \frac{J_F - V}{(1 - \beta_F)}$$

Where $\beta_M > \beta_F$ would represent lower bargaining power for women than for men.

The match surplus equations for both types of matches (male and female) are the following:

$$S_M = W_M - U_M + J_M - V \qquad S_F = W_F - U_F + J_F - V$$

The free-entry condition holds, implying that the Bellman value of a vacancy is null. And finally, steady-state unemployment (derived from their law of motion equation) is defined as:

$$\bar{u}_M = \frac{\lambda\phi}{\lambda + \theta^{1-\mu}} \qquad \bar{u}_F = \frac{\lambda(1 - \phi)}{\lambda + \gamma\theta^{1-\mu}}$$

Where ϕ is the portion of the workforce that is male.

Using the equations above, we can express all endogenous variables of the model as a function of parameters (See all model solutions in Appendix 6.1.).

3. Calibration, Empirical Results, and Quantitative Analysis

Our model aims to capture the observed gender pay gap of 10.7% and analyse how various policy interventions could influence the factors contributing to such a wage disparity. To do so, we calibrate all parameters of the model except γ with empirical data from the UK labour market, and then calibrate γ to match the 10.7% wage gap (See full model calibration in Appendix 6.2.) which yields the following:

$$\boldsymbol{r} = \mathbf{0.39\%},\ \boldsymbol{\lambda} = \mathbf{0.573\%},\ \boldsymbol{k} = \text{£}\mathbf{3,333.38},\ \mathbf{y} = \text{£}\mathbf{6,536.74},\ \mathbf{T} = \mathbf{6.2\%},$$

$$\mathbf{b} = \text{£}\mathbf{405.28},\ \boldsymbol{\mu} = \mathbf{0.72},\ \boldsymbol{\phi} = \mathbf{0.513},\ \boldsymbol{\beta_M} = \mathbf{0.623},\ \boldsymbol{\beta_M} = \mathbf{0.535},$$

$$\boldsymbol{\gamma} \approx \mathbf{0.0856531}$$

Using these parameters we get the following outputs for our variables of interest (figure 1):

Figure 1: Calibrated Model (Pre-Policy)

```
Surplus for Male Workers (Surplus_m): 7345.321
Surplus for Female Workers (Surplus_f): 152300.3
Market Tightness (Theta): 2.142937

Men's Wages (Wage_m): 6104.804
Women's Wages (Wage_f): 5451.59

Value of Being Employed (W_m): 10629.73
Value of Being Employed (W_f): 86150.06

Value of Being Unemployed (U_m): 6060.944
Value of Being Unemployed (U_f): 4669.376

Job Value for Men (J_m): 2776.531
Job Value for Women (J_f): 70819.66
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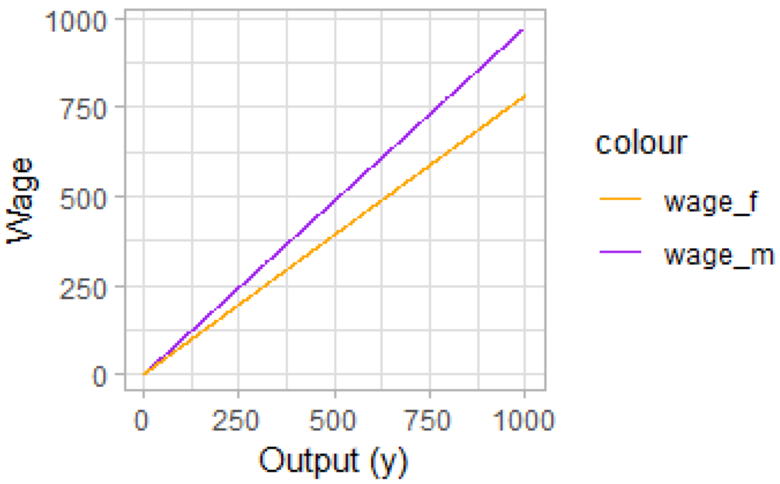
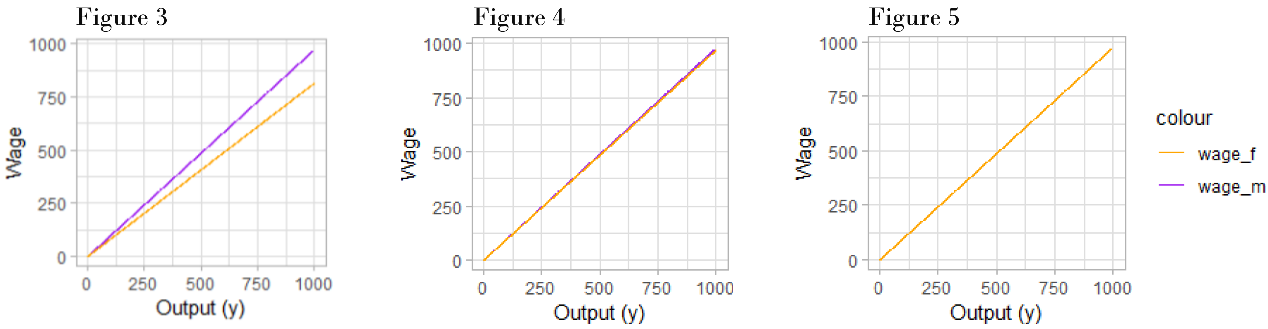
To verify that our model describes lower wages for women than men as a scale effect rather than a level effect, we run a simulation of how wages vary in function of y (figure 2 below).

Figure 2 : Wages as a Function of y



We run the same simulation twice more, the first time setting $\beta_M = \beta_F = 0.58$ (figure 3), the second time setting $\gamma = 1$ (figure 4), and the third doing both (figure 5), to confirm the hypotheses that $\beta_M > \beta_F$ and $\gamma < 1$ are the direct causes of the gender pay gap.



These simulations confirm the hypotheses and show us that the additional search friction for women is responsible for most of the wage disparities between men and women.

4. Policy Recommendation

Our model identifies the gender pay gap as arising from two primary factors: higher bargaining power for men compared to women ($\beta_M > \beta_F$) and greater search frictions faced by women in the labour market ($\gamma < 1$). Consequently, we categorize our policy recommendations into two distinct areas: enhancing female workers' bargaining power, and mitigating the effects of higher search frictions experienced by women.

4.1. Increasing Female Workers' Bargaining Power

Research indicates that gender disparities in bargaining power contribute to the wage gap (Kiessling, 2024). Men often engage more assertively in wage negotiations, driven by higher wage expectations. This disparity can be attributed to systemic factors that impose higher search frictions on women, resulting in lower bargaining power. Addressing these disparities can lead to a reduction in the wage gap, albeit marginally.

Relatively uncontroversial policies, e.g. media campaigns that underline female empowerment and the value of bargaining, could go some way towards eroding the differences in beta. However, if a government wanted to completely erase all differences in gender negotiation power, harsher measures could be implemented. Here, possible policies revolve around restricting the importance of individual wage bargaining, e.g. forcing all companies to advertise salaries and only pay candidates the advertised wage. This would directly eliminate all gender differences in β at the point of hiring, and future regulation would likely need to focus on eliminating differences in disparities during raise negotiations.

We note the possible limitations of our proposed policies, largely related to their costs and increased economic inefficiency. Less intrusive measures, e.g. media campaigns, bargaining training, are unlikely to have large drawbacks aside from their direct costs but are equally unlikely to completely equalize the wage gap. Increased government control over wage setting may be a far more damaging policy. While we were unable to incorporate this into our model, we caution that greater government intervention in wage setting may produce a variety of undesirable second order effects.

4.2. Tax on National Insurance (T_{diff})

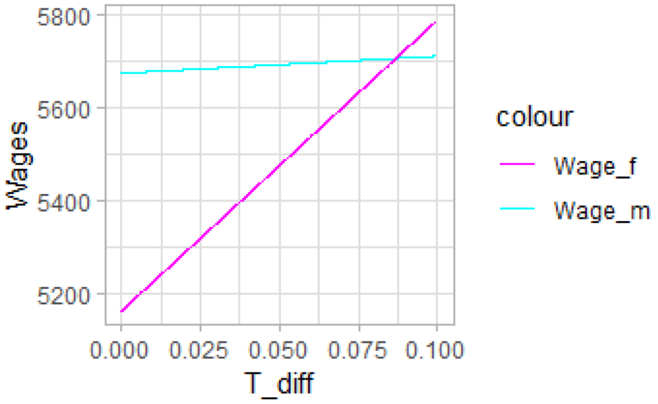
Our second and main policy to reduce gender wage disparities is the introduction of a new parameter T_{diff}, which represents the difference between the tax paid on a job filled by a man and a woman. We assume that the government aims to make all changes to payroll taxation revenue neutral and therefore require any decreases in taxation of female-produced output to be paid for by increased taxation of male-produced output, keeping the average tax rate at 6.2%.

$$\boldsymbol{T_{diff} = T_M - T_F}$$

$$where: \boldsymbol{\phi T_M + (1 - \phi) T_F = T}$$

We can see intuitively from our solved model's equations for wages, as well as in the simulation below (figure 6), that there is a positive value of $T_{diff} > 0$ for which women's wages are equal to men's.

Figure 6: Wages in Function of T_{diff}



To find the optimal levels for T_M and T_F, we assume the policies implemented the previous section were successful in converging men and women's wage bargaining power, set $\beta_M = \beta_F = 0.58$, and use our model to solve for the value T^*_{diff} where $w_F = w_M$. We can then use the equations above to find $T_M = 12.27\%$ and $T_F = 3.70\%$ (as shown on figure 7).

Figure 7: Calibrated Model at Optimal T_{diff}

```
Total Tax Rate (T): 0.062
 Tax Difference (T_m - T_f): 0.0856531
 Calculated T_m: 0.1226773
 Calculated T_f: 0.03702419

 Surplus for Male Workers (Surplus_m): 7349.806
 Surplus for Female Workers (Surplus_f): 146211.9
 Market Tightness (Theta): 2.116944

 Men's Wages (Wage_m): 5705.193
 Women's Wages (Wage_f): 5705.193

 Value of Being Employed (W_m): 9927.157
 Value of Being Employed (W_f): 89693.96

 Value of Being Unemployed (U_m): 5664.269
 Value of Being Unemployed (U_f): 4891.086

 Job Value for Men (J_m): 3086.918
 Job Value for Women (J_f): 61408.98
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We note a consequent limitation in our modelling of taxation. Payroll tax, even employer contributions, are largely paid for by decreased wages, not lower firm profits. Our representation of national insurance functions more as a form of corporate revenue taxation, and any tax reduction therefore works more akin to tax breaks or subsidies for hiring women, rather than decreasing national insurance tax for women. This model assumption was primarily done for calibration reasons and necessary limitations caused by our only partial endogenization of government spending but requires that any policy ideas for tax difference are considered more as direct corporate tax breaks for hiring women, vs. gender-specific reductions in national insurance tax. We also note potential political and legal issues, as specific gender-based tax differences may be illegal under the Equality Act.

5. Conclusion

Our model demonstrates that targeted policy interventions can effectively reduce the gender pay gap in the United Kingdom. Specifically, policies that directly subsidize female employment and those that address disparities in gender-based negotiation power show promise in narrowing wage disparities. Notably, the primary policy recommendation focuses on mitigating higher search frictions faced by women by incentivizing firms to hire more women through a differentiated National Insurance tax.

A noteworthy thought is that the need for the proposed policies (especially the tax differential) may be ephemeral. This is because as women's wages and wage bargaining power converge with men's, the exogenous factors that contribute to $\gamma < 1$ may erode due to increased normalisation of female employment, and a greater number of women in positions of power. This would mean γ gradually approaching 1 over time, in which case, it would be reasonable to argue that the tax differential should be slowly phased out, or periodically re-adjusted to match the level of γ.

A potential limitation of using our DMP search-match model is that if we look at how male workers' wages and employment rates, and total labour market welfare employment behave in function of T_{diff} (See Appendix 6.3.), we can see that they all increase as T_{diff} grows (even male employment rates, the change being infinitesimal), which seems counter-intuitive.

Ultimately, addressing the wage gap requires a multifaceted approach that extends beyond immediate economic measures to tackle underlying cultural biases and systemic barriers. Future research should explore these broader factors to complement economic policies and ensure a comprehensive strategy for achieving wage equality. This study underscores the feasibility and critical importance of implementing policies that reduce systemic inequalities in the UK labour market, paving the way for a more equitable and empowered workforce.

6. Appendix

6.1. Model (Solved)

BELLMAN EQUATIONS

$$rW_M = w_M - \lambda(W_M - U_M) \qquad rW_F = w_F - \lambda(W_F - U_F)$$
$$rU_M = b + p_M(W_M - U_M) \qquad rU_F = b + p_F(W_F - U_F)$$
$$rJ_M = (1 - T_M)y - w_M - \lambda(J_M - V) \qquad rJ_F = (1 - T_F)y - w_F - \lambda(J_F - V)$$
$$rV = -k + q_M(J_M - V) + q_F(J_F - V)$$

$$\textit{where } \boldsymbol{b} = \boldsymbol{y} * \boldsymbol{T} \textit{ and}$$
$$T \textit{ is calibrated to equal the national insurance tax, paid by the firm}$$
$$\textit{Later, we'll set our policy parameter } \boldsymbol{T_{diff} = T_M - T_F} \textit{ where } \boldsymbol{\phi T_M + (1-\phi)T_F = T}$$
$$\textit{and } \boldsymbol{\phi} \textit{ is the fraction of the total workforce that is male}$$

MATCHING TECHNOLOGY:

$$\theta = \frac{v}{u_M + u_F}$$
$$p_M = \theta^{1-\mu} \qquad q_M = \theta^{-\mu} \qquad p_F = \gamma\theta^{1-\mu} \qquad q_F = \gamma\theta^{-\mu}$$

NASH-BARGAINING:

$$\frac{W_M - U_M}{\beta_M} = \frac{J_M - V}{(1 - \beta_M)} \qquad \frac{W_F - U_F}{\beta_F} = \frac{J_F - V}{(1 - \beta_F)}$$

SURPLUS FUNCTION:

$$S_M = W_M - U_M + J_M - V \qquad S_F = W_F - U_F + J_F - V$$

FREE ENTRY CONDITION HOLDS:

$$V = 0$$

LAWS OF MOTION FOR UNEMPLOYMENT:

$$u_{M,t+1} = u_{M,t} + \lambda(\phi - u_{M,t}) - p_M u_{M,t} \qquad u_{F,t+1} = u_{F,t} + \lambda(1 - \phi - u_{F,t}) - p_F u_{F,t}$$
$$\textit{from which we obtain the steady state: } \bar{u}_M = \frac{\lambda\phi}{\lambda + \theta^{1-\mu}} \qquad \bar{u}_F = \frac{\lambda(1-\phi)}{\lambda + \gamma\theta^{1-\mu}}$$

SOLVING THE MODEL:

By substituting equations, we reduce our model to a system of 3 equations, 3 unknowns:

$$S_M = \frac{(1 - T_M)y - b}{r + \lambda + \beta_M\theta^{1-\mu}} \qquad S_F = \frac{(1 - T_F)y - b}{r + \lambda + \beta_F\gamma\theta^{1-\mu}}$$
$$k = \theta^{-\mu}\Big((1 - \beta_M)S_M + \gamma\big((1 - \beta_F)S_F\big)\Big)$$

We solve for $\boldsymbol{S_M}, \boldsymbol{S_F}$, *and* $\boldsymbol{\theta}$ *and use those values to solve for all other variables.*

SOLVING FOR WAGES:

$$w_M = (1 - T_M)y - (r + \lambda)(1 - \beta_M)S_M \qquad w_F = (1 - T_F)y - (r + \lambda)(1 - \beta_F)S_F$$

SOLVING FOR BELLMAN VALUES:

$$W_M = (1 - T_M)y + S_M(\beta_M - r - \lambda) \qquad W_F = (1 - T_F)y + S_F(\beta_F - r - \lambda)$$

$$U_M = (1 - T_M)y - S_M(r + \lambda) \qquad U_F = (1 - T_F)y - S_F(r + \lambda)$$

$$J_M = (1 - \beta_M)S_M \qquad J_F = (1 - \beta_F)S_F$$

SOLVING FOR WELFARE:

$$\boldsymbol{Wellfare} = \bar{\mathrm{u}}_M U_M + (\phi - \bar{\mathrm{u}}_M)W_M + (\phi - \bar{\mathrm{u}}_M)J_M + \bar{\mathrm{u}}_F U_F + \left(1 - \phi - \bar{\mathrm{u}}_f\right)W_F + (1 - \phi - \bar{\mathrm{u}}_F)J_F$$

6.2. Model Calibration

Interest Rate (r):

Based on the Bank of England's current annual bank rate of 4.75%. Converted to a monthly rate using:

$$r = \left(1 + \frac{4.75}{100}\right)^{1-12} - 1 \approx 0.39\%$$

Job Separation Rate (λ):

Calculated by averaging monthly redundancy rates in the UK from 1995 to 2024 (Office for National Statistics 2024).

$$\lambda \approx 0.573\%$$

Vacancy Posting Cost (k):

According to a (Glassdoor 2020) study that uses 2016 data, the average cost to fill a vacancy is £4,000.06 ; £3,000 in 2016, adjusted for inflation. Given the average vacancy lasts 4.8 weeks, or 1.2 months (Standout CV 2024), the monthly cost is:

$$k = \frac{£4,000.06}{1.2} \approx £3,333.38$$

Per-Period Output per Match (y):

Derived from the UK's GDP of £2.274 trillion and the number of employed workers (28.99 million) (House of Commons Library 2024, p9):

$$y = \frac{£2,274,000,000,000}{28,990,000 * 12} \approx £6,536.74$$

Tax Rate (T):

Reflects National Insurance contributions as a percentage of GDP from 2023-2024. This payroll tax funds unemployment benefits (HM Revenue & Customs 2024)

$$T = 6.2\%$$

Unemployment Benefit (b):

Calculated as a proportion of output:

$$b = y * T = £6{,}536.74 * 6.2\% = £405.28$$

Matching Function Elasticity (μ):

Adopted from established literature and similar models used by experts, ensuring consistency with empirical findings.

$$\boldsymbol{\mu = 0.72}$$

Fraction of Male Workers (ϕ):

Based on UK labour force data (House of Commons Library 2024, p22):

$$\boldsymbol{\phi} = \frac{17{,}090{,}000}{17{,}090{,}000 + 16{,}230{,}000} \approx \mathbf{0.513}$$

Male workers constitute 51.36% of the workforce.

Bargaining Power Parameters (β_M and β_F):

The average worker bargaining power in the UK is estimated at 0.58. Assuming women have 86% (Kiessling 2024) of men's bargaining power ($\beta_F = 0.86 * \beta_M$) due to lower wage expectations, we solve: $0.58 = \phi\beta_M + (1-\phi)\beta_F$

Substituting β_F and solving yields: $\boldsymbol{\beta_M \approx 0.623}$, $\boldsymbol{\beta_F \approx 0.535}$.

Search Friction Parameter (γ):

Calibrated using R code so that, once all the aforementioned parameters have been calculated, pre-policy ($T_{diff} = 0$), the model outputs a female wage (w_F) that is 10.7% lower than the male wage (w_M), consistent with the observed UK gender pay gap (The Fawcett Society 2023).

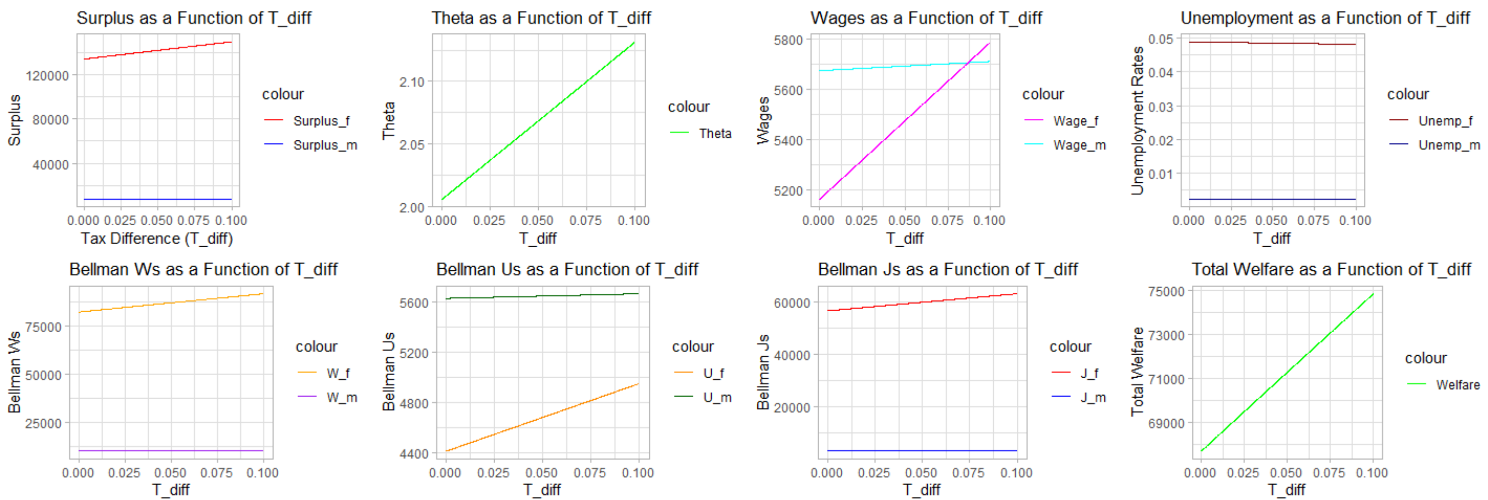
$$\boldsymbol{\gamma \approx 0.0856531}$$

Tax Difference (T_{diff}):

Used as a policy variable to examine its impact on reducing the gender pay gap. Initially set to zero to calibrate other parameters without policy intervention, optimal tax difference T^*_{diff} is found where $w_M = w_F$ (Found using R zero-solvers).

$$\boldsymbol{T^*_{diff} \approx 0.0856531}$$

6.3. All Endogenous Variables in Function of T_{diff}



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