The Impact of Fertility on Gender Wage Inequality in the UK: A COVID-19 Perspective

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Abstract
COVID-19 has significantly impacted labor markets across the world. This study examines how fertility status influences the gender wage gap in the UK and whether this impact has changed during the pandemic. Utilizing the data from UK's Labour Force Survey (LFS) from 2016 to 2023, the study employs ordinary least squares (OLS) and fixed effects regression models to examine the relationship between labor market outcomes and fertility status. The findings reveal a strong correlation between parenthood and the gender wage inequality, with women experiencing a motherhood penalty and men benefiting from a fatherhood premium. Furthermore, the COVID-19 pandemic appears to have slightly mitigated this inequality, but only to a certain extent. This study contributes to understanding gender wage inequality influenced by fertility decisions in the context of a global economic crisis.

Key words:
gender wage inequality; fertility; fixed effects; labor market; motherhood pe

1. Introduction
Despite significant gender convergence throughout the last century and decades of effort to promote equality through equal opportunity legislation, the gender wage inequality continues to be substantial across many countries, including the UK. To provide context, Figure 1 in Appendix shows the trend of gender pay gap in the United Kingdom from 1977 to 2023 conducted by the Office for National Statistics (ONS). Early literature on gender inequality in the labor market, such as Becker's (1985) work, focused on human capital theory and discrimination. According to Becker' s analysis, motherhood reduces women's hourly wages as it hinders the accumulation of human capital. The time spent on childbearing and child-rearing limits opportunities for acquiring job skills or work experience, particularly during the early stages of a career (Taniguchi, H.,1999). However, despite the reduction in gender differences in education, as documented by Blau and Kahn (2017), and the implementation of anti-discrimination policies, the persistence of the gender wage gap suggests that other factors, such as fertility, continue to play a significant role.

Based on official survey data published by the UK government, we provide a clear explanation for the persistence of gender inequality: fertility has a significant impact on women's labor market outcomes compared to men's. At the same time, understanding the pandemic's impact on gender inequalities is equally important, since gender equality essential for a nation long-term development, economic advancement, well-being and overall quality of life (World Bank, 2001; European Commission, 2015).

This study aims to evaluate the impact of fertility on labor market outcomes for women compared to men through panel data analysis using UK survey data. Based on micro-level data from the Office for National Statistics (ONS), the study examines how fertility has shaped gendered labor market dynamics in the UK from 2016 to 2023. Additionally, the research seeks to explore the influence of parenthood on the gender wage gap by addressing two key questions.

1. This study investigates the effect of fertility on the wage gap between men and women, with a firstly focus on whether a gender wage gap exists among non-parents and whether fertility exacerbates this disparity.

2. The study examines whether the COVID-19 pandemic, as an exogenous economic shock, has impacted gender wage inequality, and to what extent.

In further analysis, this research will employ ordinary least squares (OLS) regression with industry and time (quarter) fixed effects to estimate the relationship between fertility and labor market outcomes.

The main findings of this research are as follows: firstly, this study confirms that gender wage inequality remains a significant and persistent issue in the UK labor market from 2016 to 2023. This conclusion is drawn from two key observations. On one hand, a gender wage gap exists even among childless men and women, with women earning significantly less than their male counterparts. On the other hand, fertility amplifies this disparity—women experience a considerable wage penalty after becoming mothers, while men receive a wage premium after becoming fathers (Budig and England 2001; Gangl and Ziefle 2009; Budig and Hodges 2014; Cooke 2014; Kleven et al., 2019; Andrew et al., 2024). This divergence, known as the motherhood penalty and fatherhood premium, underscores the enduring structural inequalities in the UK labor market.

Secondly, the research shows that the COVID-19 pandemic has had a marginal effect on reducing gender wage inequality. Although there was a slight narrowing of the wage gap, particularly for childless women during the pandemic, the pandemic did not significantly alter the fundamental inequalities in the labor market. Telecommuting and shifts in household dynamics during the pandemic temporarily alleviated some burdens on working mothers, these changes were insufficient to disrupt the entrenched wage penalties associated with motherhood. While these findings provide valuable insights into the dynamics of gender wage inequality and the impact of fertility, it is important to acknowledge certain limitations in the study, particularly due to the lack of data availability and causality issues, may have limited the precision of the wage outcome analysis.

This study offers several key contributions to the existing literature on gender wage inequality. First, it uses recent data from 2016 to 2023, capturing the unique economic conditions shaped by the COVID-19 pandemic. Second, after confirming the existence of a wage gap between childless men and women, this study delves deeper into the motherhood penalty and the fatherhood premium. This comprehensive analysis sheds light on how fertility intensifies income inequality and underscores the complex role of parenthood in shaping wage trajectories. Third, by analyzing the pandemic's impact on gendered wage dynamics, the study adds a novel perspective to the understanding of the exogenous economic shocks. Lastly, through the inclusion of industry and time fixed effects, the research offers robust findings that emphasizes the persistence of gender wage inequality. These insights provide policymakers with valuable evidence to guide the development of targeted strategies aimed at mitigating the economic disadvantages faced by mothers and promoting more equitable labor market outcomes.

This study is organized into five sections. The first section introduces the study. Section 2 provides a literature review. Section 3 presents the research methodology and section 4 provides results and discussion. Finally, Section 5 concludes with key findings and policy recommendations.

2. Literature Review and Theoretical Framework

The research intends to uncover cause of gender pay gap in UK with a focus on the fertility cost differential by gender groups. To be specific, the study intends to check whether cost of fertility is different for male and female individuals in UK labor market. Additionally, while previous studies have extensively explored the gender wage gap, there remains a lack of focus on how parenthood, particularly in the post-COVID-19 context, reshapes income trajectories. This study aims to fill that gap. In developing the theoretical framework, this research draws on three key branches of literature: the general background of gender wage inequality, the findings on gender inequality related to fertility as confirmed in numerous prior studies, and the evolving dynamics of gender inequality in the context of the COVID-19 pandemic.

2.1 Gender wage inequality

Gender wage inequality (Adda et al., 2017) refers to the inequality of labor income between male and female workers with similar background characteristics , such as education and work experience, and is a widespread phenomenon globally (Blau and Kahn 2017). This inequality often manifests in multiple dimensions: not only do women face unequal pay for the same work, but they are also less likely to enter high paid occupations and advance to senior positions. (Weichselbaumer and Winter-Ebmer, 2005). These barriers encompass reduced opportunities for employment and promotion for female, contributing to unequal labor income across gender groups. (Kleven et al., 2019). Moreover, Kalleberg (2011, 2012) also emphasizes securing higher job positions—often less accessible to women—grants greater access to resources and economic stability, both of which are crucial for fertility decisions. This highlights how gender wage inequality not only affects immediate labor market outcomes but also has lasting implications for life choices, particularly for women.

A key contributor to gender wage inequality is discrimination against women (Bertrand and Duflo 2017), which may stem from social stereotypes or perceptions of lower productivity, such as lower average educational attainment (statistical discrimination). Indeed, deeply ingrained cultural norms significantly shape gender dynamics in the labor market. From early childhood, girls are often socialized to prioritize motherhood, with societal expectations subtly yet powerfully influencing their future family and career decisions. These long-standing expectations contribute to a broader pattern in which a “female child penalty” is transmitted across generations, reinforcing the structural barriers that women face in the labor market (Kleven et al., 2019).

However, as noted by Lundborg et al. (2017), there must be other driving factors of gender inequality in labor market. This is because that despite the persistent improvement of gender equality in education and government intervention for anti-discrimination, there is a continuous gender gap in labor market. The recent data from Graduate outcomes (LEO) study conducted by Department for Education in UK highlights that gender wage gap among fresh college graduates is relatively small, but it widens significantly over time. In the UK, male graduates were paid 10% more than their female counterparts 15 months after graduation, with this gap widening to 31% after ten years. Despite women get higher initial returns from university education, the disparity persists and grows throughout their careers, with women earning significantly less than men five years after graduation (£24,700 versus £28,300). Therefore, it is crucial to focus on the decisions individuals make after entering the labor market, as these decisions contribute to the widening of the gender wage gap. This is why numerous of literature (e.g., Glauber 2018; Weeden et al. 2016; Kleven et al., 2019), including this study, have focused on fertility as a key factor in analyzing gender wage inequality.

Overall, it is important for further investigating the effective role of fertility in contributing to these inequalities presented above. Thus, the next section will discuss how parenthood reinforces these wage gaps.

2.2 The Impact of Fertility on Gender Wage Inequality

As discussed by Glauber, R. (2018), A large part of the gender pay gap is due to the disproportionate influence of parenthood on the gender division of labor in the family. Understanding the different kinds of penalties and premiums associated with fertility is crucial, as these factors play a vital role in causing overall gender wage inequality. To be specific, women often face what is known as the motherhood penalty, a decline in earnings and career progression after having children, while men always experience a fatherhood premium, with increased earnings after they become fathers. The following sections will explore these differences in detail, looking into the factors that contribute to them and long-term effects.

2.2.1 Motherhood Wage Penalty

In this study, the primary focus is on individuals’ labor market outcomes, particularly work income. Fertility as a source of the motherhood wage penalty is widely discussed in the literature: Weeden et al. 2016, Blau and Kahn (2017) and Glauber (2018). When examining the motherhood wage penalty, we identify three main reasons from an extensive review of the literature:

Firstly, after becoming mothers, women often dedicate a significant portion of their time to family responsibilities, which leads to a reduction in their available time for paid work. This change frequently results in increased participation in part-time or flexible work arrangements. A study by Kleven et al. (2019) on Denmark measured work hours starting from 1964 and found that under traditional family values, women tend to allocate more time on family, particularly in child-rearing. Similarly, numerous studies (e.g. Budig and England 2001; Glauber 2018; Andrew et al., 2024) have pointed out that women typically shoulder greater responsibility for childcare , which limits the time and energy they can dedicate to their work (Kmec, J. A. 2011). In this context, motherhood generates public goods, such as well-raised future citizens and workers, from which society benefits without directly contributing. However, many individuals receive these benefits without contributing, effectively acting as free riders (England et al., 2016).

Secondly, due to the reduction in time allocated for personal development, women's opportunities for career advancement, continuing education, and skill enhancement are often curtailed. Moreover, employers may perceive mothers as less able to fully commit compared to childless women, which could lead to biases in hiring, promotion, and salary decisions. Research has shown that employers may reduce professional support for women based on biases and stereotypes related to motherhood, further contributing to the motherhood penalty (Correll et al., 2007; Weeden et al., 2016) as their contributions are often undervalued in performance evaluations and promotion considerations (Torres et al., 2024). As a result, the motherhood penalty is further exacerbated, deepening the inequality mothers face in the labor market.

Thirdly, career interruptions due to childbirth and child-rearing contribute significantly to the motherhood wage penalty. These interruptions often result in women taking extended periods of leave from the workforce, which disrupts their career trajectories. When mothers return to work, they face a loss of accumulated experience and skills, making it difficult to compete with peers who have remained continuously employed. Staff and Mortimer (2012) argue that interruptions in education or employment—common among mothers—further detract from career advancement and wage growth, compounding the motherhood wage penalty over time. Moreover, these disruptions can lead to skills depreciation, where a mother's work skills decline without regular use, further limiting their ability to regain prior earning potential upon returning to the workforce.

2.2.2 Fatherhood Wage Premium

The fatherhood wage premium is a well-documented phenomenon in the literature. Men who become fathers often experience wage increases relative to their childless counterparts, in stark contrast to the wage penalty faced by mothers. This premium is influenced by various factors, including cultural expectations and employer-driven biases.

Firstly, societal expectations significantly shape the fatherhood premium. For those men who born in traditional and male-headed families, they are often expected to become the future breadwinner in their own families. These culture norms, which have been reinforced for a long time, often push men to focus more on their careers after they become fathers.

This cultural expectation is consistent with role theory, which suggests that men, as the main financial providers, tend to dedicate more time and energy to their careers and prepare for taking on family responsibilities. (Hodges and Budig 2010). This increased focus on career investment often leads to higher wages for men, which in turn contributes to the growing gender wage gap between men and women.

Employer biases play a key role in reinforcing the fatherhood premium. Employers tend to view fathers as more dependable, stable, and committed to their work, assuming they have greater financial responsibilities than childless people. As noted by Bari, L. (2023), Hodges and Budig (2010) and Correll et al, (2007), fathers may be viewed by employers as more responsible and dependable, which justifies offering them higher wages. In contrast, women often face penalties due to assumptions about their reduced commitment to work, whereas men are generally viewed as more dedicated and driven to succeed professionally after having children. This perception can result in more opportunities for promotions and salary raises, further widening the wage gap.

Besides fatherhood, marital status also significantly impacts wage outcomes. Employers often view married men as more reliable compared to their unmarried counterparts. Research suggests that married fathers are favored by employers, who assume they are more responsible because of their family commitments. Research by Hodges and Budig (2010) indicates that married men, especially those with children, are often seen as the main breadwinners of their families, which results in a wage premium based on assumptions about their higher financial responsibilities. This marital premium overlaps with the fatherhood premium, further improving men’s opportunities and increasing their income.

In summary, the motherhood penalty and fatherhood premium are both deeply rooted in societal norms and reinforced by employer discrimination, which continue to drive gender wage inequality. Cultural expectations related with caregiving and breadwinning significantly shape the differing labor market outcomes for fathers and mothers (Hodges and Budig 2010; Glauber, R. 2018). Furthermore, biases from employers continue to reinforce these inequalities. Studies show that employers frequently view mothers as less dedicated to their careers, which negatively impacts their chances for promotions and wage increases (Correll, Benard and Paik 2007; Weeden et al., 2016). In contrast, fathers are viewed as more reliable and stable employees, which results in wage premiums and greater opportunities for career development (Hodges and Budig, 2010). As a result, the gender wage gap continues to widen.

2.3 Gender Wage Inequality in a COVID-19 Perspective

The COVID-19 pandemic brought unprecedented changes to the global labor market, significantly disrupting economic activities across multiple sectors. These changes further influenced existing gender inequalities (Remery et al., 2022), though the literature remains divided on the extent of the impact. After reviewing the literature, most studies support the view that the pandemic exacerbated gender wage disparities, though a smaller portion hold the opposite view. While some studies focus on the dynamic development of income inequality between men and women during the pandemic, others examine whether gender inequality has changed across different industries or demographic groups. These differing perspectives provide critical insights for this study's approach in analyzing the impact of the pandemic on gender inequality, encouraging a more nuanced and comprehensive exploration of labor market dynamics across various contexts.

Some empirical research documented that women were hit harder than men (Del Boca et al., 2020; Fodor et al., 2021; Kulic et al., 2021, Blázquez et al., 2024) due to increased responsibilities for housework and childcare. With lockdowns requiring people to stay at home and children unable to attend school or daycare, women must shoulder a greater share of domestic duties, leading to reduced work hours or complete withdrawal from the labor force. However, some studies (Dui, H., 2022; Tverdostup, M. 2023) that argue the pandemic mitigates income losses for women by suggesting that lockdowns or telecommuting helped improve work-life balance. This shift made the distribution of housework responsibilities in traditional families more equitable, allowing women to reduce the burden of childcare and allocate more time to personal development.

Moreover, the impact of pandemic is particularly pronounced for disadvantaged groups of women, such as single mothers and women with lower educational qualifications, resulting in more severe income inequality compared to men (Brini et al., 2024). Classifying groups and analyzing the varying impacts of the pandemic on different groups is a common approach in existing literature (Adams-Prassl et al., 2020; Dui, H., 2022; Brini et al., 2024). Tverdostup's (2023) research demonstrates that the impact of COVID-19 on different industries and occupations has been asymmetric. This is also evidenced by the gender pay gap in different industries published by the UK Office for National Statistics (ONS) in Figure 4 of Appendix. Although these studies are based on different countries and regions and their responses to COVID-19 are different, by identifying similarities in their conclusions, we can conclude that age, industry, education level, marital status, etc. are determinants of heterogeneous responses to the same macroeconomic shock, that is, the impact of the pandemic. This provides a foundational framework for the empirical research later in this article.

Meanwhile, some studies have suggested that the pandemic, as an ongoing economic shock, exhibits phased characteristics due to its unique infectious nature. At each stage—specifically, during periods of strict lockdown, de-escalation, and partial closures—it has had varying degrees of impact on the gender income gap. This is often referred to as short-term and potential medium-term effects in some studies (Blázquez et al., 2024). Extending the observation period and incorporating the long-term impact of the COVID-19 pandemic into economic analyzes (Clark, A. E. et al., 2021) is crucial for governments and policymakers. This approach allows for a more comprehensive understanding of the pandemic's lasting effects on gender wage disparities and enables the formulation of informed , targeted policies to address these inequalities over time.

2.4 Theoretical Framework

This research is based on the following hypotheses, which form the foundation of the research framework. This research aims to address two key questions regarding the impact of fertility on labor market outcomes in the UK between 2016 and 2023. To understand gender wage inequality, this paper provides a detailed explanation of the concepts of the motherhood penalty and the fatherhood premium, along with related research. These fertility impacts are then analyzed in the subsequent empirical model by including interaction terms of variables.

The research focuses on the labor market outcomes choose hourly income as main measurement. And several factors mentioned above, such as age, ethnicity, education level, marital status are introduced as control variables. Building on the existing literature that highlights the differential impact of fertility on men's and women's labor market outcomes, this study posits the following hypothesis:

Hypothesis 1:

Fertility exacerbates gender wage inequality in the UK labor market. Specifically, becoming a parent results in a motherhood penalty and fatherhood premium, thereby increasing the overall gender wage gap.

Hypothesis 2:

The COVID-19 pandemic has had a limited effect on reducing gender wage inequality.

While previous research has provided limited discussion on the relationship between gender wage inequality and fertility, this study focuses on the most recent six years of data, symmetrically distributed around the onset of the COVID-19 pandemic in the UK. By offering a new analysis of the impact of fertility within the context of the pandemic, this study seeks to provide valuable insights that can inform future policymaking.

3. Research Methodology

3.1 Data

To test the hypothesis, this dissertation uses the Labour Force Five-Quarter Longitudinal Dataset, which is obtained from the Labour Force Survey (LFS) and conducted by the Office for National Statistics (ONS) in the UK. The main analysis focuses on determining whether fertility is impacting labor market outcomes for females and males, specifically concerning the gender wage gap. The timeframe for this study is from 2016 to 2023, covering data from both before and after the COVID-19 pandemic outbreak, with four years symmetrically divided around the outbreak at the end of 2019. This approach effectively reveals the changes in labor market outcomes in the UK following the COVID-19.

The reasons for using LFS dataset are as follows: Firstly, the LFS employs a rotational sampling design, where once a household is selected for an interview, it remains in the sample for five following quarters. The survey utilizes stratified random sampling, collecting data from regions across the UK to ensure the representativeness of the dataset. Secondly, The LFS is the largest regular social tracking survey in the UK, and it can be constituted into panel data which includes detailed household information collected quarterly from respondents. This makes it ideal for the quantitative analysis required in this study. In addition, the analysis in this study focuses on the labor force situation, consistent with the Labor Force Survey (LFS) dataset, which is limited to individuals of working age (15-69) in the UK.

After data cleaning and addressing missing values, the analysis sample consists of 12,216 observations, with an imbalanced distribution before and after the outbreak of the COVID-19 pandemic. This imbalance is likely attributable to changes in LFS data collection methods, which, influenced by the pandemic, shifted from face-to-face to telephone interviews. The shift affects response rates and the completeness of data collection. To address this issue and minimize potential biases, this study will conduct separate regression analyses for the periods before and after the pandemic outbreak, based on the full-period regression, ensuring the robustness of the findings.

3.2 Model specifications

This study employs the main analysis by using the ordinary least square regressions (OLS) with industry fixed effects, year fixed effects and a vector of control variables to mitigate the omitted variable bias and other endogeneity issues.

Dependent variables: The study choose the natural logarithm of hourly wage as the dependent variable, consistent with previous research, including Weeden et al. (2016) and Budig and Hodges (2014). The natural logarithm is employed to address the right-skewed distribution of wages. Hourly income has two advantages compared to other income measures, such as annual labor income. First, it excludes the impact of different working length in driving annual labor income. Therefore, the difference in labor income due to self-decision about labor supply can be ruled out. Second, compared with other measurements of labor income, hourly income is less subject to the issue of measurement error.

Independent variables: This study examines the effect of several key variables on hourly wage, including female, fertility, and two interaction terms.

The variable "$female$" captures the baseline wage gap between man and women who have no child, while the coefficient of "$fertility$" reflects the effect of having children on wages for male workers.

The interaction between gender and fertility status is included to reflects the gender difference in fertility cost. Additionally, the interaction of gender and the time dummy variable is designed to assess whether the gender pay gap influenced by fertility status changes over time, particularly during the outbreak of the pandemic.

Control variables: To avoid the omitted variables biases, the regression analyses include four control variables that are documented to affect labor market performance (England et al., 2016). The confounding variables may influence the relationship and lead to biased estimates; therefore, it is essential to control for these factors: marital status, ethnicity, age and education level.

Fixed effects: Including industry and year fixed effects is crucial for obtaining reliable results. By incorporating industry fixed effects, the study controls for any time-invariant differences across industries that could influence wages, such as industry-specific wage norms, labor market conditions, or institutional practices. The year fixed effects control for temporal factors that change over time and are common across all industries, such as macroeconomic conditions, policy changes, or technological advancements.

Regression specifications: Firstly, this study attempts to analyze the relationship between gender, fertility status and their interaction effects on individual wages as the baseline regression. The model specification is shown below:

$$\ln(HOURPAY_{it}) = \alpha + \beta_1 \cdot female_i + \beta_2 \cdot fertility_i + \beta_3 \cdot (female_i \times fertility_i) + \gamma \cdot X_{it} + industry_i + \varphi_t + \varepsilon_{it} \quad (1)$$

The model incorporates key independent variables including gender ($female_i$), fertility status ($fertility_i$) and their interaction terms to capture the combined effects of these variables. Specifically, it explores how these factors jointly influence wage outcomes, accounting for the possibility that the impact of fertility on wages may differ between men and women.

The second model builds upon the baseline model by introducing an interaction term "$female_i \times post_t$" between gender and the time dummy variable (which equals one for post COVID-19 period). It is designed to assess the impact of the COVID-19 pandemic on the gender wage gap, specifically examining whether the pandemic has widened or narrowed this disparity. By including this interaction term, the model aims to capture not only effects of fertility on wages but also how these effects may have shifted during the pandemic.

$$\ln(HOURPAY_{it}) = \alpha + \beta_1 \cdot female_i + \beta_2 \cdot fertility_i + \beta_3 \cdot (female_i \times fertility_i) + \beta_4 \cdot (female_i \times post_t) + \gamma \cdot X_{it} + industry_i + \varphi_t + \varepsilon_{it} \quad (2)$$

Table 1 below defines main variables used in the analysis. Table 2 shows descriptive statistics with the mean and standard deviations for main variables.

Table 1 Description of variables

Variables	**Description**
$lnHOURPAY$	Log transformation of hourly wage

$female_i$	Gender of people (female= 1, male=0)
$fertility_i$	Fertility status (at least one child= 1, no child= 0)
$post_t$	Time dummy variable (pre pandemic= 0, post= 1)
X_{it}	Control variables (marital status, ethnicity, age and education level)
$industry_i$	Industry fixed effects, code as dummy variable
φ_t	Time fixed effects
ε_{it}	Error term

Table 2 Summary of main regression variables

VARIABLES	N	mean	sd	min	max
$lnHOURPAY$	12,216	2.699	.544	.122	6.646
$lnNETWK$	12,216	5.824	.725	.693	9.732
$lnGRSSWK$	12,216	6.062	.811	1.792	10.127
$female$	12,216	.531	.499	0	1
$fertility$	12,216	.388	.487	0	1
fem_fer	12,216	.207	.405	0	1
fem_post	12,216	.139	.346	0	1
$married$	12,216	.603	.489	0	1
edu	12,216	13.278	3.579	0	16
age	12,216	46.600	12.318	16	70

3.3 Threat to internal validity

Establishing a causal relationship between fertility and gender wage inequality, especially in the context of the COVID-19 pandemic, presents several challenges. This study acknowledges three potential threats: firstly, omitted variable biases may arise due to unobserved factors such as workplace discrimination and regional economic disparities, which could impact the analysis. However, this study uses industry and year fixed effects and a set of control variables that have been identified in the literatures to address this endogeneity and biases. Secondly, there is an expectation of reverse causality, where fertility can influence wages, and income levels can also affect fertility decisions. To mitigate this threat, the study employs multiple robustness checks, especially conducts separate regression analyses for the periods before and after the COVID-19 pandemic. By dividing the analysis across distinct time periods, the study attempts to isolate the direction of causality and reduce the risk that income is influencing fertility decisions. Thirdly, this study recognizes that the pandemic might be an external shock that could have heterogeneous affect on different demographic groups in ways that are not fully captured by the data. Therefore, controlling for industry and time fixed effects will allow this analysis to overcome the current threats to the internal validity.

4. Results and Discussion

The following section presents the results of the main analysis. It is divided into two parts, each generating results in response to the hypotheses. The first section focuses on the baseline regression model, which primarily aims to examine the impact of fertility on gender wage inequality. The second section is about the extended model which introduce an additional interaction term "$female_i \times post_t$" for capturing the period after the outbreak of the COVID-19 pandemic. This addition is intended to assess how the gender wage inequality may have been influenced by the pandemic.

In each section, the regression runs in three models. Model 1 is a basic regression model that includes the primary independent variables, along with time fixed effects (quarterly). Model 2 builds upon model 1 by introducing additional control variables, continuing to account for time fixed effects, with standard errors still clustered by individual. And model 3 is a full specification that includes all variables and both industry and time fixed effect.

4.1 The impact of fertility on gender wage inequality

Table 3 below presents the baseline regression specifications for fertility status and gender wage inequality. The standard errors in parentheses are heteroskedasticity-robust and clustered by individual. The regression results indicate that the coefficients of all the main independent variables are statistically significant.

The initial regression results presented in column 1 provide a basic analysis of the relationship between the dependent variable and the independent variables without the inclusion of control variables. The coefficient of the variable "$female$" is negative ($\beta_1 = -0.1617$), which suggests that, on average, women earn approximately 16.17% less than men when they are all childless. Additionally, the positive coefficient of variable "$fertility$" can be interpreted as a fatherhood premium. This phenomenon suggests that men experience a wage increase when they become fathers. And the interaction term "$female \times fertility$" has a coefficient (β_3) value of -0.0958 which suggests that women earn approximately 9.58% less than men when they all have children, holding other factors constant.

In column 2 and 3, the sign of the coefficients for the main variables remains consistent with column 1, and the standard errors generally decrease. Following a stepwise approach, additional control variables and fixed effects are gradually introduced into the model. Specifically, column 2 introduces controls for marital status and ethnicity, accounting for potential wage differences related to these factors. In column 3, the regression incorporates all the controls including marital status, ethnicity, education level and age, as well as the industry fixed effects. This progressive introduction of these controls enhances the robustness and reliability of the results, as the increase value of the R^2 from 0.0544 in model 1 to 0.2458 in model 3, indicating that a greater proportion of wage variation is explained by the fully specified model.

Model 3, which includes all fixed effects and control variables, illustrates the substantial gender wage gap ($\beta_1 = -0.1239$) between childless men and women. The coefficient of "$fertility$" remains positive, indicating that men experience a wage premium when they have children, reinforcing the notion of a fatherhood premium in the labor market. More crucially, the interaction term ($female \times fertility$) yields a negative coefficient of $\beta_3 = -0.0825$. This coefficient implies that women who have children face an additional wage penalty, beyond the wage inequality observed between childless individuals. In other words, women who become mothers experience both the general wage gap faced by women (β_1) and the penalty associated with parenthood (β_3). The combined effect for mothers would thus be captured by the sum of these two coefficients: $\beta_1 + \beta_3 = -0.2064$, indicating that mothers earn approximately 20.64% less than childless men. This finding confirms the differential impact of parenthood on men and women, leading to the overall gender wage inequality.

In summary, the regression results clearly demonstrate that fertility exacerbates gender wage disparities, with men benefiting from being fathers, while women experience a corresponding wage penalty from being mothers. Figure 2 and 3 in the online Appendix shows the specific gender pay gap situation based on the regression results. These findings are consistent with the results of studies by Kleven et al., (2019) and Glauber, R. (2018) and providing strong evidence that fertility status plays an important role in reinforcing gender wage inequality in the labor market. This result firmly supports the hypothesis 1.

Table 3 Baseline Regression

VARIABLES	Model 1	Model 2	Model 3
$female$	-0.1617***	-0.1601***	-0.1239***
	(0.014)	(0.014)	(0.013)

$fertility$	0.1391***	0.0946***	0.1136***
	(0.018)	(0.018)	(0.016)
fem_fer	-0.0958***	-0.0802***	-0.0825***
	(0.024)	(0.023)	(0.021)
$Married$		0.1590***	0.0873***
		(0.012)	(0.011)
$Black$		-0.0904**	-0.1008***
		(0.038)	(0.035)
$Minority$		0.0146	0.0298
		(0.027)	(0.023)
Edu			0.0495***
			(0.001)
Age			0.0056***
			(0.000)
$Industry\ FE$	NO	NO	YES
$Quarter\ FE$	YES	YES	YES
$Constant$	2.7510***	2.6691***	1.5465***
	(0.011)	(0.012)	(0.082)
$Observations$	12,216	12,216	12,216
R^2	0.0544	0.0743	0.2458

Robust standard errors in parentheses

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

4.2 The impact of pandemic on gender wage inequality

In this section, the analysis focuses on the impact of the COVID-19 pandemic on gender wage inequality by introducing an additional interaction term "$female \times post$" based on the baseline regression. Table 4 also provides the same three-model specification of the OLS regression and the value of R^2 increases from 0.0545 in model 1 to 0.2458 in model 3, which includes all controls and fixed effects.

In comparison to the baseline regression, the coefficients of key variables (i.e., "$female$", "$fertility$", and "$female \times fertility$") in Table 4 remain consistent in both sign and statistical significance. For example, in column 1 of Table 3, the value of β_1 is -0.1617 and is highly significant ($p < 0.01$). In Table 4, the variable "$female$" maintains its significance (-0.1665), still at the 1% significance level. Similarly, the coefficients for "$fertility$" and "$female \times fertility$" also remain statistically significant across all models. This consistency suggests that the underlying relationships between these variables and wage inequality are robust.

In terms of the key variable in Table 4, the coefficient of interaction term "$female \times post$" (β_4) is positive and not statistically significant across all columns, with a value of 0.0057 in column 3. This suggests that the pandemic has not had a significant additional effect on the wage inequality, which in other words, the premium for fathers and the penalty for mothers persists during the pandemic. To be specific, firstly for childless women in post-pandemic, the total wage effect can be interpreted by ($\beta_1 + \beta_4$). Secondly, for women with children, the total wage effect can be interpreted by ($\beta_1 + \beta_2 + \beta_3 + \beta_4$), reflecting both the motherhood penalty and any pandemic-related wage changes for mothers.

While the slight positive coefficient of β_4 suggests that the wage gap between childless men and women may have slightly narrowed, it remains minor. For mothers, although there may have been some wage recovery during the pandemic, the motherhood penalty has not been fully mitigated. Meanwhile, fathers continued to benefit from the steady fatherhood premium even post-pandemic.

In summary, while the results show a marginal improvement in gender wage inequality during the pandemic, these effects are small and statistically insignificant. The core wage inequality between men and women persisted through the pandemic, supporting hypothesis2.

Table 4 Extended Regression

VARIABLES	Model 1	Model 2	Model 3
$female$	-0.1665***	-0.1651***	-0.1255***

	(0.015)	(0.015)	(0.014)
$fertility$	0.1387***	0.0942***	0.1134***
	(0.018)	(0.018)	(0.016)
fem_fer	-0.0948***	-0.0793***	-0.0822***
	(0.024)	(0.023)	(0.021)
fem_Post	0.0174	0.0180	0.0057
	(0.028)	(0.028)	(0.025)
$Married$		0.1590***	0.0873***
		(0.012)	(0.011)
$Black$		-0.0906**	-0.1008***
		(0.038)	(0.035)
$Minority$		0.0147	0.0298
		(0.027)	(0.023)
Edu			0.0495***
			(0.001)
Age			0.0056***
			(0.000)
$Industry\ FE$	NO	NO	YES
$Quarter\ FE$	YES	YES	YES
$Constant$	2.7511***	2.6692***	1.5465***
	(0.011)	(0.012)	(0.082)
$Observations$	12,216	12,216	12,216

R^2	0.0545	0.0743	0.2458

Robust standard errors in parentheses

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

4.3 Result summary

This section summarizes the key findings from the regression analyses presented in Table 3 (Baseline Regression) and Table 4 (Extended Regression).

The negative coefficient of gender (e.g., -0.1239 in Table 3 and -0.1255 in Table 4) shows a wage gap between childless men and women. Even after controlling for other variables, gender differences remain significantly large. This aligns with Blau and Kahn's (2017) findings, which documented that the gender wage gap persists across industries over time. The positive coefficient of fertility status, as shown in Table 3 (0.1136) and Table 4 (0.1134), supports the concept of a fatherhood premium, where men receive wage benefits after becoming fathers, as noted by Hodges and Budig (2010). Then the interaction term between them continues to show a motherhood penalty which continues to be a significant factor in wage disparities. Even highly skilled women face substantial wage penalties after becoming mothers, as England et al. (2016) noted, these penalties are especially prominent among high-skill women. In addition, the pandemic does not fundamentally alter the inequality as the coefficient of "$female \times post$" is only slightly positive. While this result might indicate a minor shift towards improved gender equality which align with the findings in Maryna Tverdostup (2023), who noted that the telework helps in reducing gender disparities during the pandemic.

In addition to the primary variables, several control variables significantly influence wage outcomes. For instance, "marital status" consistently shows a positive and highly significant effect, with being married associated with an approximate 8.73% increase in wages, indicating that married individuals tend to have higher incomes. This aligns with research showing that marital status has a certain impact on income disparity.(Hodges and Budig 2010; Killewald and Gough 2013) Similarly, "education" is strongly correlated with wages, where each additional level of education corresponds to nearly a 5% increase in earnings, as it enhances individuals' human capital (Staff and Mortimer 2012; Blau and Kahn 2017). The "ethnicity" variable reveals a significant wage penalty for Black individuals, highlighting persistent racial disparities. Similarly, the study by Bertrand and Mullainathan (2004) found comparable results, demonstrating that discrimination in the labor market contributes to wage gaps across racial groups. Lastly, "Age" is positively associated with wage growth, as individuals accumulate more experience and seniority in the labor market. Studies, such as those by England et al. (2016), suggest that this positive relationship is particularly pronounced in higher-paying occupations, where returns to experience and tenure are greater.

In both models, the key variables maintain their signs and significance, indicating the robustness and consistency of the relationships between fertility and wage gap. The regression results confirm the persistence of fatherhood premiums and motherhood wage penalties, reaffirming the significant impact of gender and parenthood status on wage inequality.

4.4 Robustness check analysis

To ensure the reliability and validity of the regression results, a series of robustness checks were conducted in this section. These tests aim to assess the consistency of the main findings across different model specifications and time periods. Three distinct approaches are applied:

The first robustness check involves replacing the original dependent variable, hourly pay (lnHOURPAY), with two alternative income measures: gross weekly pay (lnGRSSWK) and net weekly pay (lnNETWK). This substitution allows for an assessment of whether the relationships between gender, parenthood status, and wage inequality remain stable across different income measures. Additionally, the regression is estimated both with and without the inclusion of control variables. As shown in column 1 and column 3 of Table A1, the results for the main variables remain robust across both models. The inclusion of control variables further enhances the explanatory power of the models, as the increase of R^2, particularly in the case of gross weekly pay (from 0.1049 to 0.2707).

The second robustness test incorporates all these three different dependent variables mentioned above (lnHOURPAY, lnGRSSWK, and lnNETWK), while introducing full set of control variables and fixed effects into the model. This approach provides a comprehensive check on the stability of the regression outcomes when accounting for a broader array of covariates. As presented in Table A2, coefficients of the key variables remain significant across all three models, further confirming the robustness of the results. Moreover, the inclusion of control variables and industry and time fixed effects consistently strengthens the model's fit, evidenced by improved R^2 values across specifications.

The third robustness test aims to address potential biases introduced by the COVID-19 pandemic. To account for this, separate regressions are run for the pre- and post-pandemic periods. Using the dummy variable "$post_t$" the dataset is divided into these two timeframes. Table A3 presents the results, where the coefficients of key variables remain consistent in both sign and significance across the periods. This suggests that the impact of gender and parenthood on wages are not substantially altered by the pandemic. However, there are slight shifts in the magnitude of the coefficients, which indicate a potential narrowing of wage inequality during the pandemic. These findings align with the results of the extended regression.

4.5 Limitations

This study acknowledges several limitations that could affect validity and generalizability of the findings.

Firstly, potential omitted variables may introduce bias into the analysis. While this research incorporates industry fixed effects to account for some variations, the categorization of respondents could be refined further. Other classification standards, such as occupational hierarchies or firm size, which are commonly employed in wage studies, were not included in this analysis. These factors could significantly impact wage dynamics, as position or firm size may influence not only compensation levels but also maternity leave benefits, which can alter the relationship between fertility and wages.

Moreover, although this study is limited to the UK, it does not account for differences in regional welfare policies. The UK's devolved regions—England, Scotland, Wales, and Northern Ireland—may have varying levels of childcare support, parental leave provisions and housing benefits, which can influence fertility decisions and wage outcomes. These regional disparities in welfare systems, particularly those related to childbearing, could cause geographic variations in gender wage inequality that are not fully captured in the analysis.

Thirdly, this study acknowledges the potential for reverse causality in the model. The use of OLS regression to explore how fertility impacts wage inequality may overlook the fact that income levels can also influence fertility decisions in the opposite direction. For instance, individuals with higher wages might have greater financial security to expand their family, those focused on career growth and income advancement might delay childbearing. This two-way relationship creates a potential endogeneity issue. Therefore, future research could apply instrumental variable (IV) approaches or utilize longitudinal analysis to address this. Such approaches would help to identify exogenous variations in fertility and clarify the direction of causality.

In addition, the transition of data collection methods from face-to-face to telephone interviews during the COVID-19 pandemic affected the data quality, leading to an imbalance in the sample size before and after the pandemic. As previously noted, this imbalance could potentially introduce inaccuracies, as the smaller post-pandemic sample size may not fully represent the population. While robustness checks were conducted to mitigate this issue in this study, the change in data collection methods could still impact the precision of the results, particularly when assessing wage inequality trends across time periods.

5. Conclusion

5.1 Key Findings

In conclusion, the findings of this study confirm that substantial gender wage inequality remains a persistent issue in the UK labor market from 2016 to 2023, with female workers consistently earning less than their male counterparts. This inequality is further exacerbated by fertility, where men benefit from a fatherhood premium that increases their wages upon having children, while women face a motherhood penalty, with significant wage reductions after childbirth. These patterns reflect deep-rooted structural inequalities in how gender roles and parental responsibilities influence compensation and career progression.

Moreover, the analysis also demonstrates that while the COVID-19 pandemic slightly narrowed the gender wage gap, particularly for childless women, the effects were not substantial. Although telecommuting and changes in household dynamics during the pandemic may have temporarily eased some of the burdens on working mothers, these adjustments have not been enough to significantly disrupt the longstanding wage penalties. As the strict lockdown period ended and traditional workplace structures gradually re-emerged, the gendered division of labor and its impact on wage inequality for working mothers persisted. Therefore, the motherhood penalty and fatherhood premium continue to shape wage outcomes in the post-pandemic labor market, reinforcing long-standing disparities.

Future research could apply more advanced research designs, such as incorporating instrumental variables or longitudinal studies, which would provide deeper insights into the causal relationships between fertility and gender wage gap. The data limitations in this study include the lack of detailed information on the workers' class or the type of work they perform. For example, Weeden et al. (2016) observed significant differences in work hours, particularly highlighting the impact of long work hours and part-time work on the gender wage gap. Similarly, Glauber, R. (2018) categorized workers into low, middle, and high-income groups, which provided valuable insights into the dynamics of wage distribution. Including these factors in future research could yield more comprehensive findings.

5.2 Policy Implications

These findings highlight the need for targeted policy interventions to address the persistent economic disadvantages faced by mothers in the labor market. Research from Nordic countries, particularly Sweden, shows that the introduction of non-transferable paid paternity leave has significantly increased fathers' participation in caregiving and helped reduce the gendered inequality of childbearing on wages. Additionally, expanding access to affordable childcare services and providing targeted fertility-related subsidies, such as childcare vouchers or tax credits, would alleviate the economic burden on families and support mothers' participation in the workforce.

Furthermore, the government should actively promote gender equality in the division of family responsibilities by encouraging the equal sharing of childcare and household duties between men and women. Changing cultural expectations through public policy is a gradual but necessary process. Governments can measure progress by tracking increases in paternity leave uptake and reductions in gender-based wage disparities over time, particularly in industries where traditional gender roles have been more pronounced. It is necessary to foster a more balanced sharing of domestic duties, which in turn will reduce the disproportionate caregiving burden on women.

To address persistent workplace bias, comprehensive regulations and mandatory diversity training programs must be implemented. Equal treatment of men and women after childbirth should be the norm, and transparent wage structures can help reduce gender-based pay disparities. Strengthened anti-discrimination laws, along with rigorous enforcement, are crucial in protecting mothers' employment rights and ensuring their smooth return to the workforce, fostering a more inclusive and equitable labor market.

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Appendix

Table A1

Table A1 Robust Test-1

VARIABLES	lnGRSSWK	lnGRSSWK	lnNETWK	lnNETWK
$female$	-0.3960***	-0.3071***	-0.3298***	-0.2471***
	(0.022)	(0.022)	(0.020)	(0.020)
$fertility$	0.1862***	0.1309***	0.1737***	0.1301***
	(0.024)	(0.022)	(0.022)	(0.020)
fem_fer	-0.2607***	-0.2566***	-0.2341***	-0.2304***
	(0.034)	(0.030)	(0.030)	(0.027)
fem_post	0.0517	0.0279	0.0250	0.0029
	(0.039)	(0.035)	(0.034)	(0.032)
$Married$		0.0985***		0.0773***
		(0.016)		(0.014)
Edu		0.0653***		0.0547***
		(0.002)		(0.002)
Age		0.0033***		0.0029***
		(0.001)		(0.001)
$Black$		-0.0278		-0.0018
		(0.054)		(0.047)

Minority		0.0406		0.0321
		(0.033)		(0.031)
Industry FE	NO	YES	NO	YES
Quarter FE	YES	YES	YES	YES
Constant	6.2467***	4.9313***	5.9764***	4.8081***
	(0.014)	(0.132)	(0.013)	(0.121)
Observations	12,216	12,216	12,216	12,216
R^2	0.1049	0.2707	0.0987	0.2529

Robust standard errors in parentheses

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

Table A2

Table A2 Robust Test-2

VARIABLES	lnHOURPAY	lnGRSSWK	lnNETWK
female	-0.1509***	-0.3309***	-0.2747***
	(0.012)	(0.018)	(0.016)
fertility	0.1108***	0.1275***	0.1267***
	(0.014)	(0.019)	(0.018)
fem_fer	-0.0803***	-0.2556***	-0.2288***

	(0.018)	(0.026)	(0.024)
fem_post	0.0995***	0.1165***	0.1052***
	(0.013)	(0.021)	(0.019)
$Black$	-0.1010***	-0.0281	-0.002
	(0.030)	(0.046)	(0.040)
$Minority$	0.0303	0.0405	0.0323
	(0.020)	(0.028)	(0.027)
$Married$	0.0836***	0.0950***	0.0733***
	(0.010)	(0.014)	(0.012)
Edu	0.0500***	0.0657***	0.0552***
	(0.001)	(0.002)	(0.002)
Age	0.0057***	0.0033***	0.0030***
	(0.000)	(0.001)	(0.001)
$Industry\ FE$	YES	YES	YES
$Quarter\ FE$	YES	YES	YES
$Constant$	1.5566***	4.9558***	4.8275***
	(0.074)	(0.122)	(0.114)
$Observations$	12,216	12,216	12,216
R^2	0.2395	0.2656	0.2469

Robust standard errors in parentheses

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

Table A3

Table A3 Robust Test-3

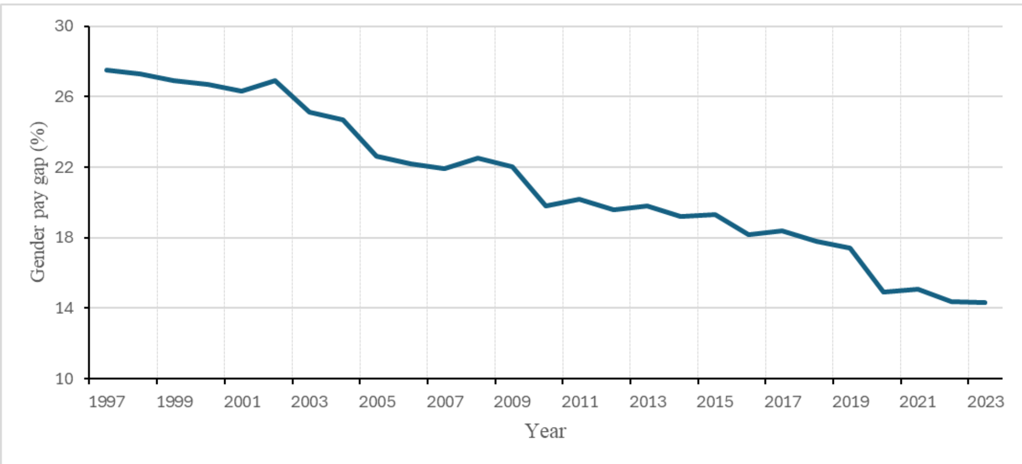
VARIABLES	lnHOURPAY	lnHOURPAY
$female$	-0.1301***	-0.1073***
	(0.015)	(0.028)
$fertility$	0.1104***	0.1235***
	(0.018)	(0.037)
fem_fer	-0.0707***	-0.1181**
	(0.023)	(0.047)
$Black$	-0.1168***	-0.0428
	(0.038)	(0.083)
$Minority$	0.0317	0.0244
	(0.026)	(0.049)
$Married$	0.0830***	0.1012***
	(0.012)	(0.025)

Edu	0.0505***	0.0456***
	(0.002)	(0.004)
Age	0.0059***	0.0048***
	(0.001)	(0.001)
$Industry\ FE$	YES	YES
$Quarter\ FE$	YES	YES
$Constant$	1.4588***	1.8310***
	(0.086)	(0.202)
$Observations$	9,101	3,115
R^2	0.2561	0.1967

Robust standard errors in parentheses

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

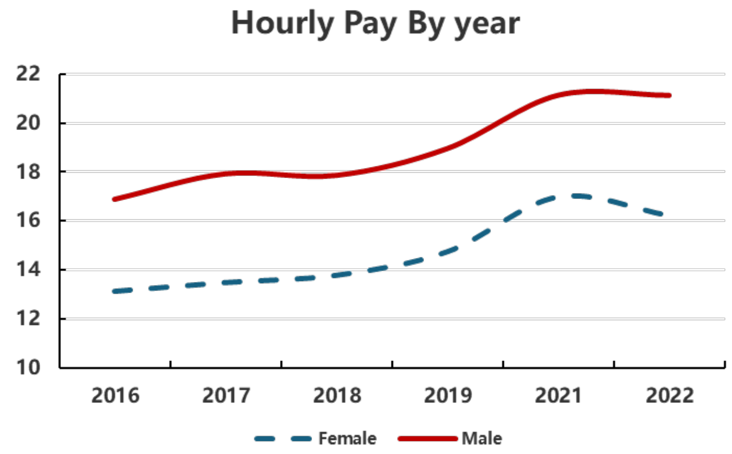
Figure 1



Source: Data from the Office for National Statistics (ONS)

Figure 1: Trend of gender pay gap in the United Kingdom,1997-2023

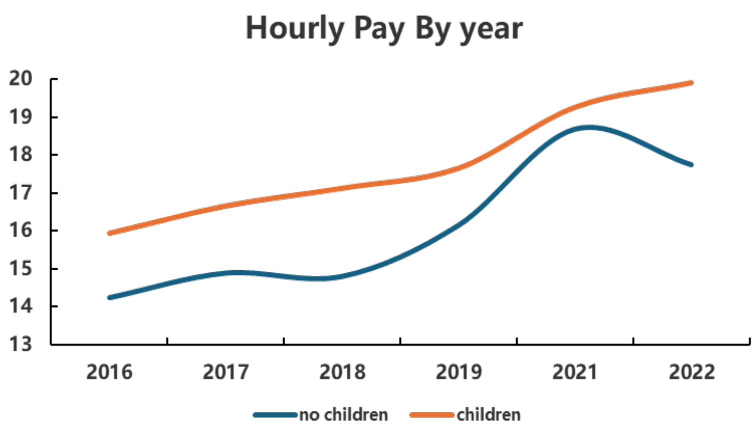
Figure 2



Source: Regression Result

Figure 2: Gender pay gap by year

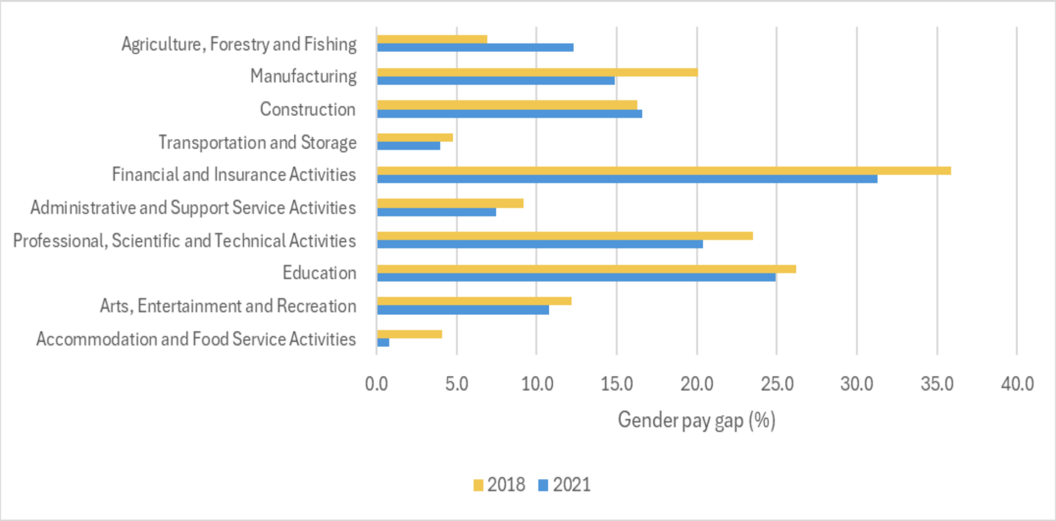
Figure 3



Source: Regression Result

Figure 3: Hourly Pay By year

Figure 4



Source: Data from the Office for National Statistics (ONS)

Figure 4: Gender pay gap by Industry

Conflict of Interest Statement

The author(s) declare no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.