Explaining the Gender Gaps in Unemployment across OECD Countries*

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Abstract

There is substantial heterogeneity in the gender gaps in unemployment across OECD countries. We incorporate labor market institutions, moral hazard and home production into a quantitative model of unemployment. The model can explain most of the observed gender gaps. We also investigate the quantitative importance of each model component in replicating the empirical data. The results suggest that high taxes, high replacement rates, large pay gaps, and low productivity levels are associated with high unemployment rates and large gender gaps.

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1 Introduction

In this paper, we analyze the gender gaps in unemployment across OECD countries, which is illsutrated in Figure 1. Gender gaps in unemployment are very persistent and

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dispersed across countries. In the literature, while closely related questions such as gender gaps in wages and labor force participation have been studied extensively, gender gaps in unemployment have not been studied explicitly other than a few exceptions.[1,2] The aim of this paper is to fill this gap using a quantitative model of unemployment which is an extended version of Hansen and Imrohoroglu (1992).

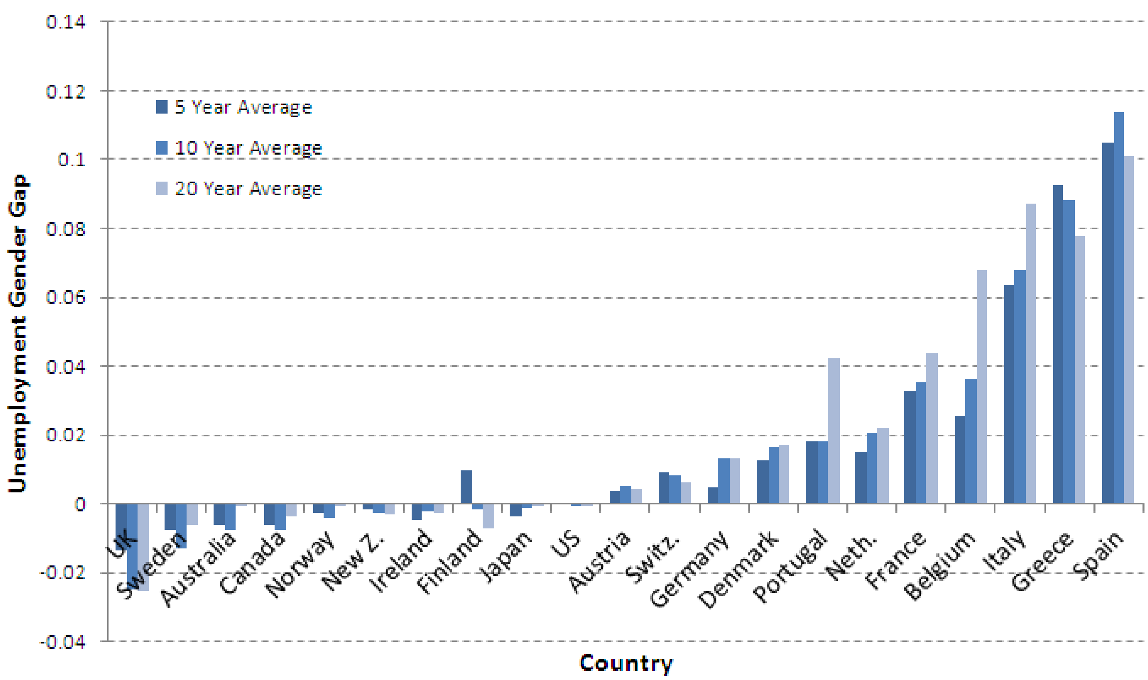
Motivated by the high level of persistence over time and the high degree of variation in the gender gaps in unemployment across countries, we postulate that the heterogeneity and the persistence of labor market institutions such as earning tax rates, unemployment benefit levels and durations, average hours of work, average earnings, and gender wage gap are potential candidates for explaining gender gaps in unemployment. A quantitative model of unemployment in which we augment the aformentioned country-specific labor market features is able to successfully replicate the cross-country unemployment gender gap data. In particular, the model explains 88% of the unemployment gender gap variation across countries.

The model we use is an extension of the incomplete-markets model of Hansen and Imrohoroglu (1992) in which, workers face idiosyncratic employment risk which can be partially insured through savings, home production, and unemployment benefits. Eligibility for unemployment benefits depends on govenment monitoring over job offers. Monitoring is costly and is determined endogenously by the government to maximize the average utility in the society. There is both ex-ante and ex-post heterogeneity in the society. The population consists of two gender and three earnings groups. Individual's wage and gender is realized in the beginning of his or her life and assumed to be fixed over time. On the other hand, his or her employment state depends on idiosycratic shocks over time and that creates an ex-post heterogeneity in the society in terms of savings.

[1]See Gunderson 1989, Blau and Kahn 1992,2003, and Black and Spitz-Oener 2010 for wage gender gap. See Blundell et al. 2007, Fogli and Veldkamp 2011, and Olivetti 2006 for labor force participation gap.

[2]See Albanesi and Sahin (2013), Azmat et al. (2006).

Figure 1: Gender Gaps in Unemployment Across OECD Countries (Source: World Development Indicators)



We calibrate the model using earning tax rates, unemployment benefit levels and durations, average hours of work, average earnings, and gender wage gap data of 21 OECD countries. In addition to country specific parameters, we set some parameters to their standard valuies in the literature. Finally, we choose the parameters of government monitoring cost and home production to match gender gaps in unemployment and average unemployment rates in the corresponding set of countries.

The quantitative model is successful in replicating most of the gender gaps. There is a few exceptions including France, New Zealand and United Kingdom. We think of it as a natural consequence of the fact that we use a limited number of economic factors that would possibly affect gender gaps in unemployment in the model. Enriching the model with additional country-specific factors would probably improve the results for the aforementioned countries. In addition to replicating the empirical data on unemployment gender gaps, we also perform some comparative statics exercises. In particular, we investigate the effects of specific factors on unemployment gender gaps in a selected set of countries representing various labor market institutions. The quantitative results based on the model economies for France, Italy, Norway, and U.S. indicate that high taxes, high replacement rates, large pay gaps, and low productivity levels are associated with high unemployment rates and large gender gaps.

This paper is closely related to Albanesi and Sahin (2013), and Azmat et al. (2006). Albanesi and Sahin (2013) develop a search model of unemployment to explain the decline in unemployment gender gap in the U.S. and find that the developments in female and male labor market attacment behavior explains this fact quite well. They also suggest that gender differences in industry distribution explains the cyclical movements in unemployment gender gap. Azmat et al., on the other hand, empirically study the factors that can potentially explain observed gender gaps across countries. In particular, they use micro data across several OECD countries and find that differences in human capital accumulation between women and men interacted with labor market institutions explains the unemployment gender gaps. We differentiate from the aforementioned studies in the sense that we use a heterogeneous agent framework, a rich set of labor market institutions, and home production in our model. As a result we are able to study the interactions of several key components of the labor market and home production with wealth and gender heterogeneity in the society, and provide an explanation for the gender gaps in unemployment.

The rest of the paper is organized as follows: Section 2 gives brief information about the data. We provide a static model and some theoretical results in Section 3. We specify a heterogeneous-agent dynamic model economy in Section 4. and explain the calibration in Section 5. In Section 6 we present the results. In Section 7 we propose some extensions for future work and conclude.

2 Data

In this section we present cross-country data on labor market institutions and gender gaps in unemployment. We obtain unemployment gender gap series from the World Development Indicators database. Table 2 reports the 5-, 10-, and 20-year averages of gender gaps in unemployment across countries. There is substantial heterogeneity in gender gaps in unemployment across countries which varies between -1.36% (United Kingdom) and 10.50% (Spain), and the coefficient of variation across countries is equal to 1.96.

We obtained the values in Table 3 from the OECD database, which presents the replacement rates and potential duration of unemployment benefits, average hours of work, taxes on earnings, and the mean and standard deviation of these variables across

OECD countries.[3] Standard deviations of these variables implies significant dispersion in labor market institutions across these countries.

Unemployment benefit systems, which are described by replacement rate and potential duration, vary quite dramatically across countries. Most of the European countries have benefit systems more generous than that of the US. The countries that have low replacement rates tend to have longer duration of benefits. Australia, the UK, New Zealand, and Ireland have the longest potential durations and the lowest replacement rates. On the other hand, countries with generous replacement rates tend to limit the duration. Sweden, Portugal, Denmark, Norway, and some others, limit benefits to shorter durations.

In Table 4, we report the gender pay gap and earning distribution of female and male workers.[4] The gender pay gap is defined as the ratio of female average earnings over male average earnings; the lower this value is the higher the gender pay gap is. We combine these empirical facts in a quantitative model and explain most of the gender gaps in unemployment across OECD countries.

3 Theoretical Analysis

In this section we present a static model and obtain theoretical results to develop an intuition and to highlight the mechanisms of the dynamic model. The agents in this economy receive job offers and decide whether to accept or reject it. If an agent accepts a job offer, he or she earns a market wage rate of y and he or she has to pay a τ percent earning tax. Labor is indivisible and each employed worker is assumed to work for h hours. If agents choose to reject a job offer, they will not earn any market wage however

[3] The fraction of lost earnings which is paid as unemployment benefits is called "replacement rate."
[4] Calculation of the income distributions is explained in detail in the Appendix.

they can do home production to maintain his or her consumption. We denote home production with φ and asset level with m. There is an unemployment insurance system to support the involuntarily unemployed agents. The unemployed agents who are entitled will receive unemployment insurance benefits, which are $\theta\%$ of the after-tax market wage. We assume that the government cannot perfectly monitor the agents: π percent of the agents who reject the job offers still get the unemployment insurance benefit (a moral hazard problem).

The maximization problem of an agent who receives a job offer is the following:

$$Max\{V_{reject}, V_{accept}\}$$

where

$$V_{reject} = \pi U(\theta(1-\tau)y + m + \varphi, 0) + (1-\pi)U(m + \varphi, 0)$$

$$V_{accept} = U((1-\tau)y + m, 1-l).$$

In the above equations, $U(.,.)$ is the utility function where the first argument is consumption and the second argument is leisure. We assume that the utility function is additively separable in consumption and labor and it is logarithmic.

$$U((c,h) = \log(c) + \log(1-l)$$

where l is the level of the labor supply. Agents who reject the job offers will get the unemployment insurance benefits with probability π and consume $\theta(1-\tau)y + m + \varphi$ (we assume that home production and the market good are additive) if they receive the benefits. They will not receive unemployment benefits and consume $m + \varphi$ with probability $(1-\pi)$. When they reject job offers, labor supply equals 0, i.e. $h=0$. If an agent accepts a job offer, his or her consumption will be $(1-\tau)y+m$ and his or her labor supply will be equal to $h>0$.

Agents will reject job offers if $V_{reject} > V_{accept}$. Once we impose the functional form of the utility into the above condition, we get:

$$\pi \log(\theta(1-\tau)y+m+\varphi)+(1-\pi)\log(m+\varphi) > \log((1-\tau)y+m)+\log(1-l). \quad (1)$$

After some algebra the condition simplifies to:

$$[\theta(1-\tau)y+m+\varphi]^{\pi}[m+\varphi]^{1-\pi} > [(1-\tau)y+m](1-l). \quad (2)$$

We use conditions (1) and (2) to derive the theoretical results of this section. We first start with the effect of the unemployment insurance benefit level (replacement rate) on accepting or rejecting a job offer.

Proposition 1 *Given other parameters, there exists a replacement rate θ^* such that if $\theta > \theta^*$ the agents will reject the job offers. Otherwise the agents will accept the job offers. The critical level of benefit, θ^*, is*

$$\theta^* = \frac{\left(\frac{[(1-\tau)y+m](1-l)}{[m+\varphi]^{1-\pi}}\right)^{\frac{1}{\pi}} - m - \varphi}{(1-\tau)y}. \quad (3)$$

Proof. Note that the value of rejecting a job offer is increasing with the replacement rate θ, whereas the value of accepting a job offer does not depend on the benefit level. Next, we equate the value of rejecting to the value of accepting a job offer to obtain a closed-form solution shown in equation 3. ■

Proposition 2 *θ^* decreases if home production, φ, increases.*

Proof. This is easily seen from equation 3. If φ increases, the numerator deceases, which decreases θ^*. ∎

Suppose that there are two kinds of economies, one with home production, φ, and one with no home production. Keeping everything constant, agents in the first economy would have a lower θ^* value. Therefore, a home production sector in an economy tends to increase the fraction of agents who would reject job offers. Moreover, interaction of home production - as a mechanism that increases the value of being unemployed - with labor market institutions would affect the labor supply decision of workers even further. Therefore, having a home production in our full model is quantitatively important.

Proposition 3 *If $(y+m)h > \theta y + m + \varphi$, then there exists a tax level τ^* such that $1 > \tau^* > 0$, and if $\tau > \tau^*$, agents will reject job offers; otherwise they will accept.*

Proof. If $\tau = 1$, then the value of rejecting will be higher than the value of accepting, since φ is positive and h is between 0 and 1.

$$m + \varphi > mh$$

If $\tau = 0$, then using the assumption that $(y+m)h > \theta y + m + \varphi$, we obtain that the value of accepting is larger than the value of rejecting. To see this, observe that $(y+m)h$ is the value of accepting a job offer when the tax rate is 0. The value of rejecting a job offer in this case is $[\theta y + m + \varphi]^{\pi}[m + \varphi]^{1-\pi}$. The fact that $\theta y + m + \varphi > m + \varphi$ implies $\theta y + m + \varphi > [\theta y + m + \varphi]^{\pi}[m + \varphi]^{1-\pi}$. Since both values of rejecting and accepting are continuous functions of τ, then there should exist a $\tau^* \in (0,1)$ such that both functions intersect. Since both functions are monotonic, they intersect only once, which implies that if $\tau > \tau^*$, agents will reject job offers; otherwise, they will accept. ∎

The condition $(y+m)h > \theta y + m + \varphi$ is imposed to guarantee that τ^* is positive. If we remove the condition, then it is possible that τ^* will be negative. In such a case, for all values of possible taxes, the agents will reject the job offers. The next proposition shows how τ^* changes with home productivity φ.

Proposition 4 *If $h > \theta\pi$, then τ^* is decreasing with home production, φ.*

Proof. The critical value of the tax, τ^*, can be obtained by equating the value of rejecting to the value of accepting.

$$\pi \log(\theta(1-\tau^*)y + m + \varphi) + (1-\pi)\log(m+\varphi) = \log((1-\tau^*)y + m) + \log(h) \tag{4}$$

Implicitly differentiating equation 4 gives

$$\frac{\pi(-\frac{\partial \tau^*}{\partial \varphi}\theta y + m + 1)}{\theta(1-\tau^*)y + m + \varphi} + \frac{1-\pi}{m+\varphi} + \frac{\frac{\partial \tau^*}{\partial \varphi} y}{(1-\tau^*)y + m} = 0.$$

Solving for $\frac{\partial \tau^*}{\partial \varphi}$ gives

$$\frac{\partial \tau^*}{\partial \varphi} = \frac{\frac{1-\pi}{m+\varphi} + \frac{\pi(m+1)}{\theta(1-\tau^*)y+m+\varphi}}{\frac{\pi\theta y}{\theta(1-\tau^*)y+m+\varphi} - \frac{y}{(1-\tau^*)y+m}}. \tag{5}$$

The numerator of equation (5) is positive. The denominator of equation (5) is negative if $\frac{\theta}{\theta(1-\tau^*)y+m+\varphi} - \frac{1}{(1-\tau^*)y+m}$ is negative (since π is smaller than 1). Dividing both the numerator and the denominator of $\frac{\theta}{\theta(1-\tau^*)y+m+\varphi}$ with θ gives the result that if $\frac{m+\varphi}{\theta} > m$, then $\frac{\theta}{\theta(1-\tau^*)y+m+\varphi} - \frac{1}{(1-\tau^*)y+m}$ will be negative. Since we assumed that home productivity, φ, is positive and the replacement rate, θ, is smaller than 1, $\frac{m+\varphi}{\theta} > m$ will always be true. As a result, equation (5) implies that $\frac{\partial \tau^*}{\partial \varphi}$ is negative. ■

We now turn to the importance of asset level for the agents' accepting or rejecting decisions.

Proposition 5 *There exists a critical asset level m^* such that if $m > m^*$, agents will* *reject the job offers. Otherwise they will accept.*

Proof. If the asset level goes to $-\varphi$, then agents will certainly accept the job offers due to the fact that consumption will go to zero in case of a rejction. If the asset level goes to infinity, the slope of V_{reject} goes to 1, whereas the slope of V_{accept} is h (it is constant and smaller than 1). As a result V_{reject} and V_{accept} should intersect at some m. The intersection point is m^*. As the slope of V_{reject} is larger than the slope of V_{accept} for the asset levels $m > m^*$, V_{reject} will be larger than V_{accept} for $m > m^*$. ■

Proposition 5 implies that households with higher asset levels, keeping the other factors constant, are more likely to reject the offers and become unemployed. The reason is that the richer households can use their assets to insure against the possibility that they do not get insurance after rejecting.

4 Dynamic Model

In this section we incorporate labor market institutions, moral hazard, and home production into a quantitative model of unemployment which is based on Hansen and Imrohoroglu (1992) to explain unemployment gender gaps. Key ingredients of the model are idiosynratic employment risk, home production, endogenous government monitoring over job offers, and wage dispersion.

Ex-ante Heterogeneity in the Population The population consists of a continuum of infinitely lived agents that are heterogeneous regarding their earnings. Women and men differ from each other in terms of their income distributions.[5] Ex-ante, we have three groups in the society, namely, $\{(y^{ij})\}$, where $i \in \{f, m\}$, and $j \in \{L, M, H\}$. Each gender has three earning groups, low (L), medium (M), and high (H).

[5] Gender pay gap is a well established result in the empirical literature. See Kunze (2000) for a detailed survey.

We allow for earning heterogeneity to embed progressive earning taxes (higher earners pay higher taxes) and unemployment benefits (in most countries, replacement rates are higher for lower earning groups).

Employment Process There is wage heterogeneity in the model economy; however, there is no transition between the income groups. Therefore, each individual faces income risk only through unemployment shocks. In each period, agents receive job offers according to a stochastic process that is specified by a two-state Markov chain, χ. If an agent receives a job offer, he or she has the *opportunity* to work for $\hat{h}$ hours (this means labor is indivisible) and earn wage y^{ij}, depending on her/his gender and earning group. If an agent does not receive a job offer or refuses a job offer, then he or she will be unemployed for that period.

Household Preferences Agents enjoy utility from a consumption good, leisure and a public good, and maximize their expected lifetime utility:

$$E\sum_{t=0}^{\infty}\beta^{t}U(c_{t}^{ij},l_{t}^{ij},G) \tag{6}$$

where β is the discount factor, c_t^{ij} is total consumption, and l_t^{ij} is the amount of time devoted to leisure by an agent with gender i, and earning j at time t. The third factor in the utility function is a public good, denoted by G, and provided by the government.[6] The total consumption of an agent with gender i and earning j in period t equals:

$$c_t^{ij} = \left\{ \begin{array}{l} c_{m,t}^{ij} + \varphi, \text{ if the agent is unemployed} \\ c_{m,t}^{ij}, \text{ if the agent is employed} \end{array} \right\}$$

where φ is home production and $c_{m,t}^{ij}$ is consumption of the market good for an agent with gender i and earning j at time t. We assume that total consumption is the sum of market

[6] We include a public good in the model in order to have a balanced government budget.

consumption and home production. For simplicity, we assume that home production is only possible when the agents are not working in the market.[7] The home-produced goods are assumed to be consumed within the period of production.[8]

The utility function follows:

$$U(c,l,G) = \frac{(c^{1-\sigma}l^{\sigma})^{1-\rho} - 1}{1-\rho} + \psi \log(G) \tag{7}$$

Consumption and leisure are aggregated with Cobb-Douglas function and the aggregate good is formulated as a Constant Relative Risk Aversion (CRRA) utility function. Both functional forms are quite standard in the literature. The utility from the public good is assumed to be logarithmic and separate from private consumption.

Agents do not have any private insurance besides a storage technology, which is a non-interest bearing asset:

$$m_{t+1}^{ij} = m_t^{ij} + y_t^{d,ij} - c_{m,t}^{ij} \tag{8}$$

where m_t^{ij} is the asset holdings, $y_t^{d,ij}$ is the disposable income of an agent with gender i and earning j at time t. The disposable income will be different from earning y_t^j, because of the earning tax, τ_y, and unemployment benefit eligibility. The disposable income of individuals and the unemployment benefit system are explained later on.

Unemployment Benefits In practice, only actively searching unemployed are eligible for unemployment benefits up to a certain period of time. However, it is also

[7] This is a simplifying assumption; however, allowing the employed agents to do home production would not change the results, because the important point is the difference in home production during unemployment and employment spells. Burda and Hamermesh (2010), and Guler and Taskin (2013) provide empirical evidence on the substantial difference between home production times of unemployed and employed using the U.S. micro data.

[8] Here, c_t^m can be interpreted as the consumption good that agents buy from the market and φ can be interpreted as the home production that agents do at home, such as cooking, cleaning, repairing, child care, etc. Sum of the two components gives total consumption.

possible to avoid government monitoring and obtain benefits. The model mimics the system in practice in the sense that all agents who do not receive a job offer will receive unemployment benefits (b) up to a certain number of periods (a). Agents who refuse job offers will receive unemployment benefits with probability π, which pins down the level of monitoring in the model ($1-\pi$ is the monitoring level). The level of monitoring is assumed to be optimally chosen by the government to maximize social welfare. Better monitoring decreases the moral hazard problem, on the other hand it is assumed to be costly. We assume that the cost of monitoring is linearly increasing in the monitoring level:

$$\xi(\pi) = \delta(1-\pi), \tag{9}$$

where δ is a positive constant.

The unemployment insurance system can be summarized as the following:

$$\begin{array}{lcl}
\text{No job offer, } a \leq a_{\max} & \Rightarrow & \mu = 1, \text{ gets benefits} \\
\text{No job offer, } a > a_{\max} & \Rightarrow & \mu = 0, \text{ no benefits} \\
\text{Gets an offer, accepts} & \Rightarrow & \mu = 0, \text{ no benefits} \\
\text{Gets an offer, rejects} & \Rightarrow & \mu = 1, \text{ gets benefits with probability } \pi \\
 & & \mu = 0, \text{ does not get benefits with probability } 1-\pi
\end{array} \tag{10}$$

where μ is an indicator that takes a value of 1 if the agent receives benefits, and 0 if he or she does not receive benefits. Upon qualifying for unemployment benefits, an agent with previous earnings y^{ij} receives an amount of $\theta_{y^{ij}}(1-\tau_{y^{ij}})y^{ij}$, where $\theta_{y^{ij}}$ is the net replacement rate for an agent with earning y^{ij}.[9]

[9]Note that the replacement rate depends on the level of lost earnings; therefore, we denote with θ_y,

Earning Tax and Disposable Income Government levies tax on earnings progressively; that is, the rate of linear tax, τ_y, decreases as the level of earnings increases. The parameters of the tax system are calibrated with the numbers used n practice for each country, which is explained in detail in Section 5. The government uses the tax revenues to finance the unemployment insurance program and to provide a public good.

Disposable income of an agent is determined by employment status, level of earnings, and qualification status for unemployment benefits, and can be summarized as follows:

$$\text{No job offer } (s = u), (\mu = 1) \Rightarrow \quad y_t^{d,ij} = b \tag{11}$$

$$\text{No job offer } (s = u), (\mu = 0) \Rightarrow \quad y_t^{d,ij} = 0 \tag{12}$$

$$\text{Job offer } (s = e), \text{accepts} \Rightarrow \quad y_t^{d,ij} = (1 - \tau_{y^{ij}})y^{ij} \tag{13}$$

$$\text{Job offer}(s = e), \text{rejects}, (\mu = 1) \Rightarrow \quad y_t^{d,ij} = b \tag{14}$$

$$\text{Job offer}(s = e), \text{rejects}, (\mu = 0) \Rightarrow \quad y_t^{d,ij} = 0 \tag{15}$$

where $y_t^{d,ij}$ represents the disposable income of an agent in gender group i, and earning group j at time t. An agent with no job offer receives unemployment insurance benefits, $b = \theta_{y^{ij}}(1-\tau_{y^{ij}})y^{ij}$, if α, the number of consecutive periods of benefits received, is smaller or equal to $\alpha_{\max}$, the maximum potential duration.

An employed agent has a disposable income that equals the after-tax earnings $(1 - \tau_{y^{ij}})y^{ij}$. An agent who qualifies for benefits upon refusing a job offer (that is, he or she is not monitored by the government) receives unemployment benefits b if α is smaller than or equal to α_{max}. If he or she does not qualify for the benefits upon refusing a job offer (that is, he or she is monitored), then he or she has 0 disposable income in that period.

Recursive Formulations We formulate the problem of agents in a recursive form

instead of θ.

to compute equilibrium numerically.

No Job Offer Case: Agents with no job offer, $s = u$, receive unemployment insurance benefits unless, α, the number of consecutive periods of benefits received is greater than $\alpha_{\max}$, the maximum number of consecutive periods of benefits allowed. The generosity of unemployment benefits, θ^y, is changing with the level of income. The problem of an agent in gender group i, and earning group j who receives no job offer is to choose the optimal amount of assets for the next period. As they do not work, their leisure time will be equal to the total time endowment of 1:

$$V^{ij}(m, u, \alpha) =$$

$$\max_{m'}\{U(m + (1 - \tau_{y^{ij}})\theta_{y^{ij}} y^{ij} - m' + \varphi, 1) + \beta \sum_{s'} \chi(u, s')V^{ij}(m', s', \alpha')\}$$

$$\text{subject to } 0 \leq m'$$

$$\alpha' = \alpha + 1 \text{ if } \alpha \leq \alpha_{\max}$$

$$\alpha' = 0 \text{ if } \alpha = \alpha_{\max}$$

In the above equation, m denotes asset accumulation. Job offers are assumed to be generated from an exogeneous two-state Markov process, χ. In this case, since agents don't receive job offers, transition is from unemployment to other states, $\chi(u, s')$.

Job Offer Case: An agent who receives an employment opportunity has an option to reject it. Moral hazard possibility arises in this case.The government is assumed to be unable to monitor job offers perfectly, thus unable to detect UI eligibility of agents perfectly. Therefore, an agent who receives a job offer might find it optimal to reject it and receive benefits afterwards with some positive probability (π). Those who reject job offers will realize whether they receive benefits or not upon refusing the job offer. Afterward, they make their consumption/saving decisions. Those who accept job offers receive an exogenous wage rate and do not face any uncertainty; hence they directly make their consumption/saving decisions.

$$
\begin{gathered}
V^{ij}(m,e,\alpha) = \\
\max\{\max_{m'} U(m + (1-\tau_{y^{ij}})y^{ij} - m', 1-\hat{h}) + \beta \sum_{s'} \chi(e,s')V^{ij}(m',s',0), \\
\pi \max_{m'} U(m + (1-\tau_{y^{ij}})\theta_{y^{ij}} y^{ij} - m' + \varphi, 1) + \beta \sum_{s'} \chi(e,s')V^{ij}(m',s',\alpha') + \\
(1-\pi)\max_{m'} U(m - m' + \varphi, 1) + \beta \sum_{s'} \chi(e,s')V^{ij}(m',s',\alpha')\} \\
\text{subject to } 0 \le m' \\
\alpha' = \alpha + 1 \text{ if } \alpha \le \alpha_{\max} \\
\alpha' = 0 \text{ if } \alpha = \alpha_{\max}
\end{gathered}
$$

Equilibrium An individual state is denoted with $x = (i,j,m,s,\alpha)$. Let $\lambda(x)$ be the invariant distribution of the agents, $c(x)$ the consumption decision, $m(x)$ the saving decision, and $\eta(x)$ the employment decision. In the stationary competitive equilibrium, the agent's decision rules $c(x)$ and $m(x)$ solve the dynamic planning problem. The good market clears,

$$
\sum_x \lambda(x)c(x) + G = \sum \lambda(x)\eta(x)y^{ij}. \tag{16}
$$

Government is assumed to have a balanced budget constraint. It raises revenues from taxes on earnings and unemployment benefits, and spends on the unemployment insurance system and a public good.

$$
\begin{aligned}
&\underbrace{\sum \lambda(i,j,m,1,\alpha)\eta(i,j,m,1,\alpha)y^{ij}\tau_{y^{ij}}}_{\textit{tax return from the workers}} \\
&\underbrace{+\sum \pi\lambda(i,j,m,1,\alpha)(1-\eta(i,j,m,1,\alpha))\tau_{y^{ij}}\theta_{y^{ij}} + \sum \lambda(i,j,m,0,\alpha)\tau_{y^{ij}}\theta_{y^{ij}}}_{\textit{tax return from the insured}} \\
&\underbrace{-\sum\{\lambda(i,j,m,0,\alpha)\theta_{y^{ij}}y^{ij} + (1-\pi)\lambda(i,j,m,1,\alpha)(1-\eta(i,j,m,1,\alpha))\theta_{y^{ij}}y^{ij}\}}_{\textit{insurance expenditure}} \\
&- \underbrace{G}_{\textit{public good expenditure}} = 0
\end{aligned}
\tag{17}
$$

The invariant distribution should satisfy the following functional equation:

$$
\lambda(i,j,m,s,\alpha) =
\begin{cases}
\sum_{s'}\sum_{m\in\Omega} \chi(s',u)\lambda(i,j,m,u,\alpha-1) & \text{if } s=u,\ \alpha\le\alpha_{\max} \text{ and } \alpha>0 \\
\sum_{s'}\sum_{m\in\Omega} \chi(s',e)(1-\eta(i,j,m,e,\alpha-1))\lambda(i,j,m,e,\alpha-1) & \text{if } s=e,\ \alpha\le\alpha_{\max} \text{ and } \alpha>0 \\
\sum_{s'}\sum_{m\in\Omega} \chi(s',e)\eta(i,j,m,e,\alpha)\lambda(i,j,m,e,\alpha)+\lambda(i,j,m,e,\alpha_{\max}) & \text{if } s=e,\ \alpha=0 \\
\sum_{s'}\sum_{m\in\Omega} \lambda(i,j,m,u,\alpha_{\max}) & \text{if } s=u,\ \alpha=0
\end{cases}
\tag{18}
$$

where Ω is defined as the set of state space that will give the optimal asset level m from the model.

The government maximizes the total welfare subject to its budget constraint and cost function:

$$\begin{gathered}\underset{\pi}{Max}\sum_{x}\lambda(x)E[U(c(x),\eta(x)] \\ subject\ to\ equations\ (9)\ and\ (17).\end{gathered} \tag{19}$$

5 Calibration

We calibrate the model parameters in three steps. First, we set some preference parameters to their standard values in the literature. These parameter values are assumed to be the same for each country. We set β to 0.995, which corresponds to an annual discount rate of 4 %, and σ to 0.67, both are standard in the literature. The value of parameter ρ is set to 5, which corresponds to a risk aversion of 2.3 for consumption good (c), which is within the standard range of 1.5-4.0 in the literature. We choose the values of the transition probability matrix similar to those in Hansen and Imrohoroglu (1992). The chosen transition matrix gives an involuntary unemployment level of 6%,[10] and an average duration of 12 weeks (two periods) without job offers. The corresponding transition matrix is as follows:

$$\begin{bmatrix} .97 & .03 \\ .5 & .5 \end{bmatrix}$$

In the second step, we obtain the country-specific values of the parameters that represent labor market institutions from the OECD database. The average hours of work, denoted by $\hat{h}$, is set to the empirical average working hours of the corresponding country. We normalize this value by dividing working hours by total hours. The values of parameters $\theta_{y^{ij}}$, α, and $\tau_{y^{ij}}$ are set to replacement rate, potential duration of unemployment benefits and earning tax of the corresponding country. Note that tax and replacement

[10] This is the fraction of agents who do not receive a job offer.

Table 1: Benchmark Parameters

Parameter	Explanation	Value
β	Discount factor	0.99
σ	Utility function	3
ρ	Utility function	.67
ψ	Utility function	0.057
$\chi(e,e)$	Employment process	.97
$\chi(u,e)$	Employment process	.5
φ	Home production	0.067
δ	Monitoring cost	0.012

Notes: These parameters are common in calibration of the model for each country. The country specific parameters are reported in Table 3 and Table 4.

rates depend on earnings with a progressive nature. The chosen parameter values are reported in Table 3.

The values of parameters y^{ij} and κ_i^j are calculated from the data for each country and fed into the model. The calculation method is explained in detail in the Appendix and the calculated values are reported in Table 4.

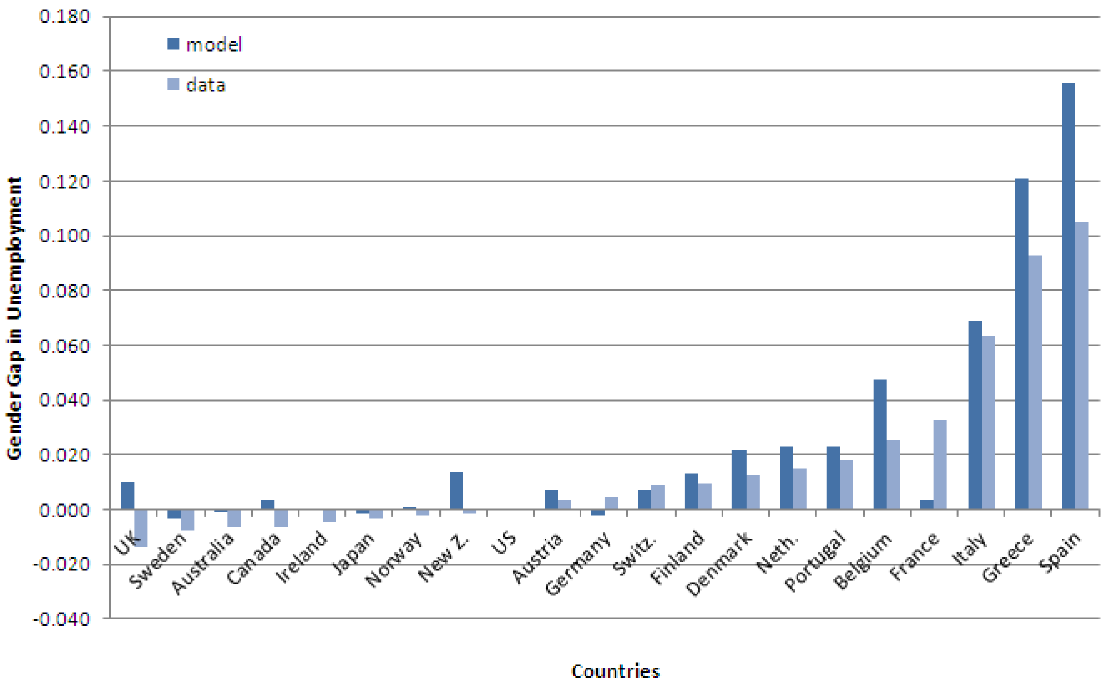
Finally we calibrate the values of parameters φ and δ to match the gender gaps across countries. We do not calibrate these parameters separately for each country, but we use the same values for each country to match the entire set of countries. The corresponding values for the selected parameters are reported in Table 1.

6 Results

6.1 Model Predictions

To obtain the gender gaps in unemployment for each country, we solve the model for each country separately. The model predictions are compared with the data in Figure 2.

Figure 2: Gender Gaps: Data vs Model



One should keep in mind that we do not include some variables in the model that could potentially improve our results.[11] Among others, these additional variables could be educational differences across countries and different marriage and fertility rates across countries. In fact, some of these factors are considered by Azmat et al. (2006), and they are found to generate small gender gaps. So the small deviations from the data can be attributed to those factors.

The heterogeneity in labor market institutions together with home production generates most of the heterogeneity in gender gaps across countries (Figure 2). The coefficient of variation in gender gaps is 1.96 and 1.72 in data and model, respectively. The calibrated versions of the model for the high and moderate gender gap countries match the empirical data quantitatvely. Among the moderate gender gap countries, the only excep-

[11] We can include only a certain number of factors in the model due to computational limitations.

tion is France. The empirical level of the gender gap in France is around 3%; however, the model generates a gender gap below 1%. Among the zero and negative gender gap countries, the model's performance is quite well except for New Zealand and the United Kingdom. Empirical gender gaps in these countries are -0.14% and -1.4%, however the model generates 1.4% and 1%, respectively. This is a result of the fact that the model we use contains only a limited number of economic factors that would affect the gender gap in unemployment. Imposing more country-specific factors would probably improve the results for the aforementioned countries.

The rate of unemployment is determined by two dynamics: the first is the exogenous process that generates employment opportunities, and the other is the accept/reject decisions of individuals. Since the exogenous process of employment opportunities is the same for each country and gender, the heterogeneity in the unemployment rate across genders and countries is created by the accept/reject decisions of individuals. This decision is affected by the key ingredients of the model, which are labor market institutions, home production, and imperfect monitoring of job offers (moral hazard).

In countries where there is no gender gap or small gender gaps, both women and men tend to accept all job offers. For the other countries, the decomposition shows some heterogeneity. For example, gender gaps in Belgium, Germany, the Netherlands, Norway, Canada, and Switzerland mostly arise from the decisions of women. In these countries, men mostly tend to accept job offers, while some women turn them down. For Denmark, Finland, France, and Portugal the gender gap is affected by both female and male tendencies to refuse job offers. In general, due to the interaction of labor market institutions, gender pay gap and home production in these countries, women tend to refuse job offers more frequently in comparison with men, and that generates the gender gap in unemployment in the model.

We perform additional quantitative exercises to see the effect of specific factors on the size of gender gap in unemployment. The results indicate that high taxes, high replacement rates, large pay gaps, and low productivity levels are associated with high unemployment rates and large gender gaps.

6.2 Contributions of Specific Factors to Gender Gaps in Unemployment

In this section, we analyze the effects of specific factors on the quantitative results.[12] We solve the model with various values of the pay gap, tax rate and replacement rate parameters. At each exercise, we change one parameter and keep the rest fixed to see the effect of the given parameter on the quantitative results.

Here, we limit our attention to four countries: France, Italy, Norway and the U.S. We choose these countries because they represent different kinds of economies. The U.S. has comparatively low taxes on labor, low replacement rates, and comparatively high working hours. France has high taxes, high replacement rate, and comparatively low hours of work. Norway has high taxes, moderate replacement rate, and very low hours of work. Italy has high taxes, low replacement rates and the moderate hours of work. Due to this heterogeneity, the countries reflect various responses to the changes in selected factors.[13]

[12] Taking taxes, replacement rate, and hours of work as state variables, and solving the unemployment rates as a function of these variables would be ideal for this kind of analysis. Since this is computationally infeasible, we do not solve the model across all possible combinations of these variables. Instead, we set these variables consistent with the values in practice for each country and solve the model accordingly.

[13] In this section, we see discontinuity in most of the results presented in figures. The main reason for this result is the limited level of heterogeneity in the model (only three levels of earnings). The limited earnings and wealth heterogeneity results in a distribution with little dispersion. Therefore, a significant mass of agents respond in the same direction when we change a labor market institution in the model, which causes the observed jumps in the figures.

6.2.1 Role of Replacement Rate

The effect of unemployment benefits on the rate of unemployment has always been an important discussion in both Europe and the U.S. In general, economic theory suggests that unemployment rates increase in response to increased unemployment benefits by discouraging job search intensity.[14] On the other hand, empirical literature reports weak positive relationship between unemployment benefits and unemployment rates.[15] Our findings suggest that the small coefficients might be due to nonlinearity of the relationship between the unemployment rate and the benefit levels. Our model implies that low levels of replacement rates do not affect the unemployment rates. However, after some threshold level it starts to cause higher unemployment rates in our quantitative exercises.

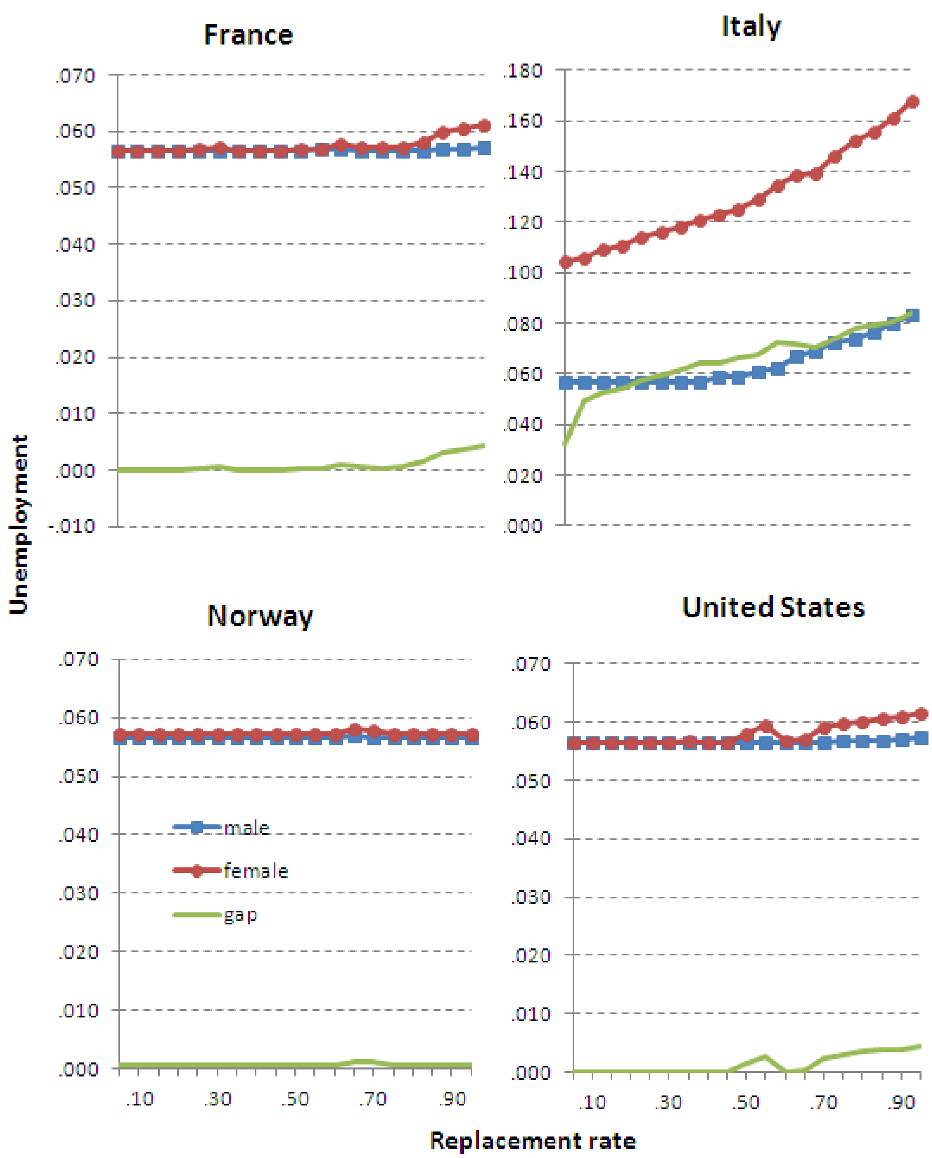
For each selected country, we solve the model with various values of replacement rates to see its quantitative effect on results. The replacement rate of the median earner takes the value of each .05 increment in [.05,.95] interval. Recall that we have a progressive replacement rate profile (higher earnings in employment spells imply lower replacement rates in unemployment spells). Therefore, we adjust the replacement rate of low and high earning groups proportionately consistent with the system in practice.

Figure 3 reports the results. The values in the horizontal axis of the figure represent the median earner's replacement rate. The figure shows that, in the calibrated model for the French economy, unemployment rate does not increase in response to the changes in replacement rate at moderate levels. This happens for two reasons: first, the high tax rates imply a high level of optimal monitoring for unemployment benefits qualification, because the cost of monitoring is financed with taxes; second, the average hours of work is low; therefore, the value of being unemployed (relative to being employed) is smaller compared to the countries where the average hours of work is high. That makes employ-

[14] See, for instance, Hopenhayn and Nicolini (1997).

[15] See Krueger and Meyer (2002) for a detailed survey.

Figure 3: Replacement Rates vs Gender Gap in Unemployment



ment stable in the model economy when calibrated to French data. Moreover, female unemployment starts to increase when replacement rates are greater than 80% of lost earnings due to the lower earnings of women in this economy. In Norway, unemployment responds similarly for the same reasons. However, female unemployment is stable even at even very high replacement rates, because the pay gap is very small and average earning is very high in this economy.

When we calibrate the model to the U.S. data, the model economy responds similar to France in terms of increasing unemployment rates with increased unemployment benefits. However, the reason for the increase in unemployment is high working hours rather than high earning taxes.

In the model economy for Italy, female unemployment rate increases even with low replacement rates. This is because of the very large pay gap in this economy. The male unemployment rate is stable until the 50% replacement rate and increases after then.

6.2.2 Role of Taxes

Tax rate is a determinant of unemployment rate in the model, because it affects the value of employment through earnings. Figure 4 illustrates the effect of taxes on female and male unemployment rates. We look at the effects of taxes from 5% to 70% with 5% increments, and we fix the values of the rest of the parameters to their benchmark values. As depicted in the figure, the rate of tax is quantitatively important. As the rate of tax increases, agents tend to refuse job offers more frequently, because the value of employment decreases through reduced after-tax earnings. The responses of unemployment rates to an increase in tax rates differ across countries, because there is heterogeneity in their labor market institutions. In the model economies for U.S. and Italy, unemployment rates increase immediately above 30-40% of taxes on earnings. This is because of the high hours of work - which reduces the relative value of employment - in these countries. Note that Italy is more responsive to taxes, because average earnings are smaller in this country. We also observe an increase in the gender gap in unemployment in both countries. It increases more in Italy, because the pay gap is much larger compared to the U.S.

When we calibrate the model with French data, unemployment increases after 60% of earnings tax. In France, the threshold level of taxes that creates high unemployment is higher compared to the U.S. and Italy due to the lower average hours of work in this economy which increases the value of employment. In the model economy for Norway, the unemployment rate does not increase, although the tax level increases up to 70%. This is due to the very high average earnings and very low average hours of work, which creates a high value for employment in this economy.

6.2.3 Role of Pay Gap

In this exercise the ratio of the average earnings of women to the average earnings of men takes values between 0.50 and 0.95 with 0.05 increments. The results show that in the calibrated versions of our model for France, Italy, and the U.S., the gender gap in unemployment is increasing with the increase in the pay gap between men and women. The rate of increase in the gender gap in unemployment depends on the interaction with labor market institutions in these economies. In Italy and France, even very low levels of the pay gap create a gender gap in unemployment due to high earning taxes.[16] In the U.S. economy, the gender gap in unemployment happens after moderate levels of pay gaps due to low earning taxes. In the model economy for Norway, even if the pay gap becomes very large, the gender gap in unemployment does not increase due to very low hours of work and high average earnings in this economy. The results are illustrated in

[16] Recall that, in the model, female unemployment rate responds more aggresively to the changes in earning taxes (Figure 4).

Figure 4: Earning Tax Rate vs Gender Gap in Unemployment

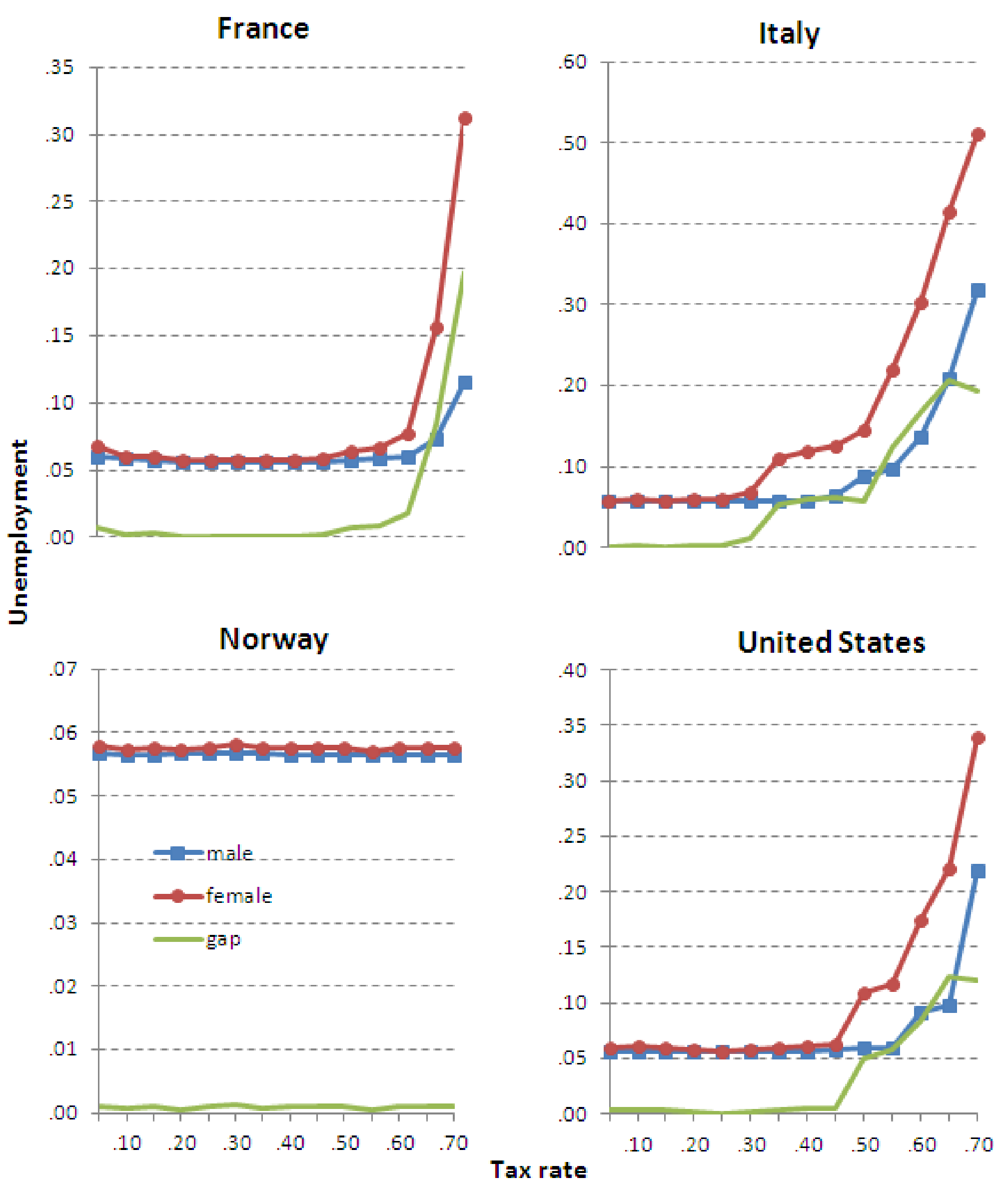


Figure 5.

6.2.4 Role of Productivity

In this section, we analyze the effect of productivity levels on the rate of male and female unemployment. For each country, we consider productivity levels between .20 and 1.00. Figure 6 shows the response of each country to the changes in productivity levels. The model economies of France, Italy and the United States respond similarly: the gender gap in unemployment starts from about .40 and diminishes gradually and goes to 0 as productivity increases. However, in Norway, the gender gap in unemployment gets zero much earlier than in the other three economies. This happens due to very low average hours of work in this economy. Low hours of work increase the value of employment and workers stop rejecting job offers right after the wage rate goes above .30.

7 Discussion and Conclusion

We propose a quantitative unemployment model to explain the gender gaps in unemployment rate in the OECD countries. The components of the model are home production, pay gaps, unemployment benefits, earning taxes, hours of work and imperfect government monitoring of job offers. The results indicate that model is successful in replicating the empirical data. We also investigate the role of specific factors in model's performance and find that all ingredients have quantitative importance to match the empirical data.

We make two important assumptions in the model. First, we do not include out of the labor force as an employment status in the model (i.e., individuals are either employed or unemployed). The findings of Azmat et al. (2006) provide empirical support for this assumption. Using micro data from OECD countries, they find that transitions

Figure 5: Pay Gap vs Unemployment Gender Gap

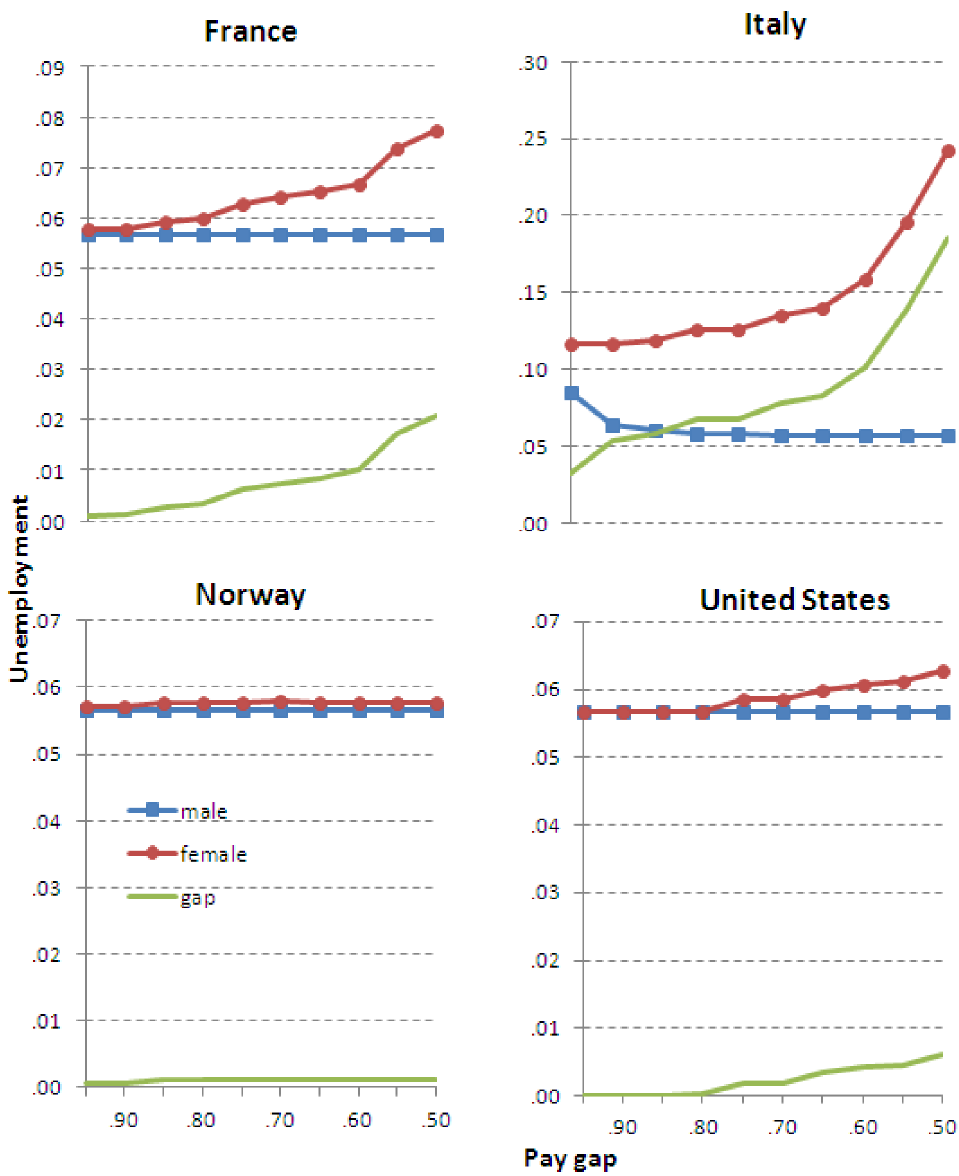
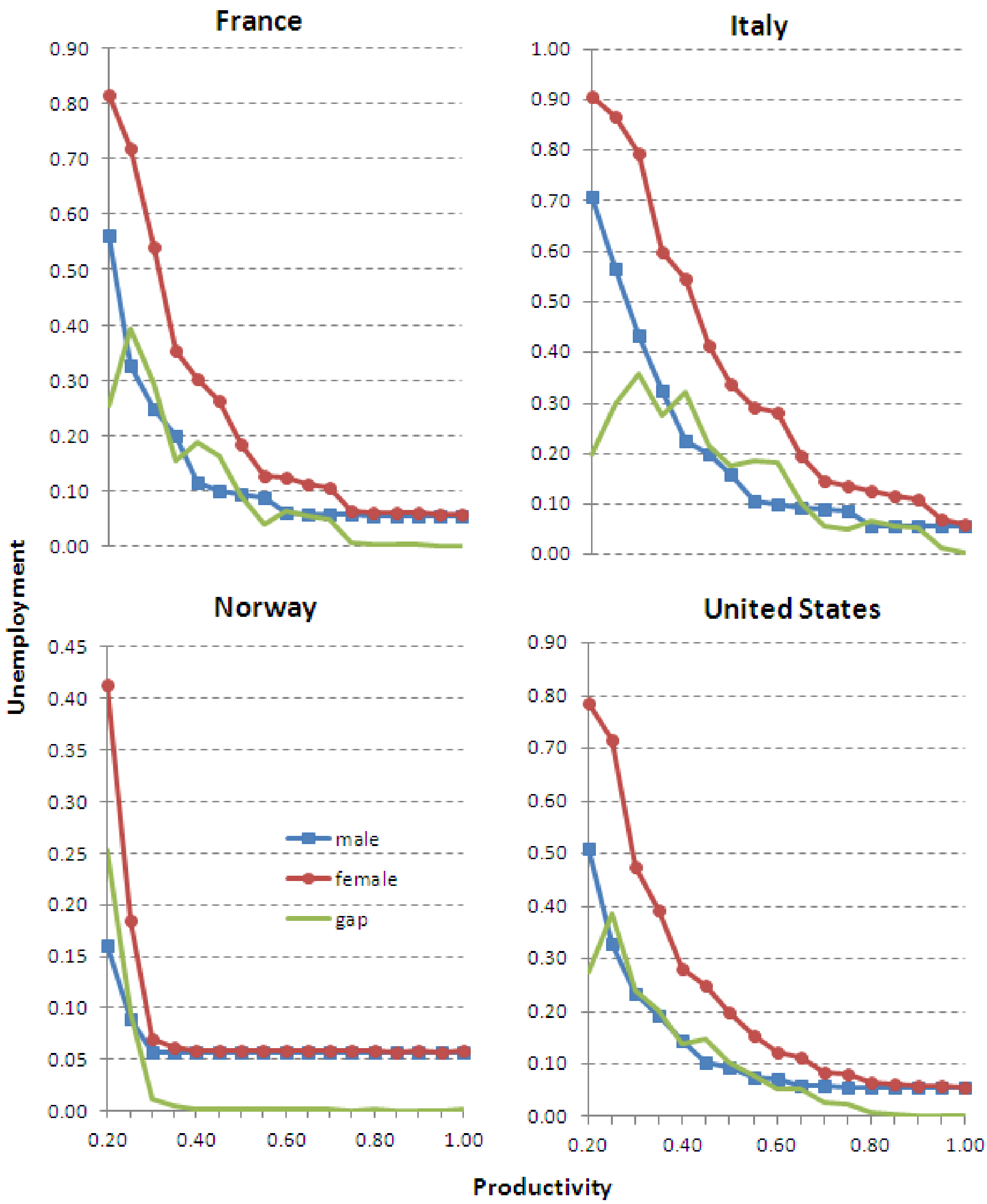


Figure 6: Productivity vs Gender Gap in Unemployment



into and out of inactivity are not important in explaining the rate of unemployment. The second assumption is the imperfect monitoring of the unemployment insurance qualification. Both the existence of imperfect monitoring and the significant effects of imperfect monitoring on the unemployment levels have empirical support. Lalive et al. (2005) show that the enforcement of the rules and the unemployment levels are negatively related. Johnson and Klepinger (1994) find strong evidence that more stringent search requirements reduce the unemployment spell. Dolton and O'Neil (1996) study the effect of search requirements on unemployment using the Restart experiment performed in the UK. They find that the notification of monitoring had a statistically significant positive effect on the transition from unemployment to employment.

Our quantitative exercises also contributes to the discussion on the high unemployment rates in Europe.[17] The model we used in this paper implies that high replacement rates and high earning taxes reduce employment. Since earning taxes and replacement rates increased in Europe between 1960 and the 1980s, we guess that this might have contributed to the high unemployment rates in Europe over the corresponding time period.

[17] For the European unemployment discussion, see Blanchard (1998), Ljunqvist and Sargent (1998), and Blanchard and Wolfers (2000).

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8 Tables

Table 2: Gender Gaps in Unemployment

	5 Year Average	10 Year Average	20 Year Average
Australia	-0.62	-0.77	-0.08
Austria	0.36	0.53	0.42
Belgium	2.54	3.63	6.78
Canada	-0.62	-0.75	-0.34
Denmark	1.26	1.66	1.69
Finland	0.96	-0.16	-0.72
France	3.28	3.53	4.39
Germany	0.48	1.32	1.3
Greece	9.26	8.81	7.78
Iceland	0.6	0.6	0.61
Ireland	-0.48	-0.21	-0.28
Italy	6.34	6.78	8.72
Japan	-0.36	-0.11	-0.02
Netherlands	1.5	2.07	2.18
New Zealand	-0.14	-0.25	-0.31
Norway	-0.24	-0.41	-0.07
Portugal	1.8	1.83	4.22
Spain	10.5	11.38	10.09
Sweden	-0.74	-1.32	-0.61
Switzerland	0.92	0.83	0.63
UK	-1.36	-2.47	-2.54
US	0.04	-0.05	-0.06
Mean	1.60	1.66	1.99
St. Dev.	3.16	3.39	3.47

Notes: 5-year averages are computed by averaging over gender gaps between years 1997-2002. The 10-year and 20-year averages are obtained similarly. The data is comparable across countries, because ILO definition of unemployment is used for each country. Source: World Development Indicators (2004).

Table 3: Labor Market Data

	θ_L %	θ_M %	θ_H %	α_{max} years	$\hat{h}$ hours	τ_L %	τ_M %	τ_H %
Australia	45	31	23	4	1870	39.4	35.6	45.0
Austria	55	55	55	2	1600	56.3	59.9	41.4
Belgium	83	63	46	4	1580	71.3	66.5	68.4
Canada	65	62	43	1	1740	34.2	40.7	35.9
Denmark	84	61	47	2.5	1510	42.1	43.5	62.8
Finland	73	60	48	2	1770	52.8	56.9	56.9
France	77	73	67	3	1650	63.2	52.0	59.7
Germany	62	61	62	4	1600	58.1	63.3	44.3
Greece	71	48	34	1	1900	50.8	50.8	57.4
Ireland	42	30	23	4	1750	35.9	54.8	54.8
Italy	50	54	46	0.5	1730	53.6	53.6	61.5
Japan	70	60	50	0.5	1960	29.9	34.2	33.6
Netherlands	81	71	59	2	1510	49.0	46.5	50.0
New Zealand	53	37	26	4	1830	21.0	34.0	38.0
Norway	65	66	53	1.5	1430	43.1	51.1	53.7
Portugal	81	78	84	0.8	2000	47.1	47.1	55.6
Spain	76	69	48	3.5	1820	45.2	48.1	37.0
Sweden	82	77	55	1.2	1510	46.3	47.9	66.9
Switzerland	80	70	71	1	1640	32.5	35.8	42.6
United Kingdom	63	45	31	4	1750	38.8	38.8	47.7
United States	62	62	45	0.5	1940	34.4	34.4	43.7
Mean	67.62	58.71	48.38	2.24	1718.57	45.00	47.40	50.33
St. Dev.	12.99	13.79	15.63	1.39	164.66	11.97	9.84	10.47

Notes: θ_L, θ_M, and θ_H denote the replacement rate for low, medium and high earning groups. It is defined as the ratio of unemployment benefit level to labor income prior to unemployment. α_{max} is the maximum potential length of benefit receipt. $\hat{h}$ is the average annual hours of worked per worker. τ_L, τ_M, and τ_H denote the tax rates for low, medium and high earning groups. Sources: Nickell (1997,2003), OECD Benefits and Wages (2002, 2004), OECD Employment Outlook (2005).

Table 4: Labor Market Data, Cont'd

	y^L	y^M	y^H	κ_f^L	κ_f^M	κ_f^H	κ_m^L	κ_m^M	κ_m^H
Australia	0.696	1.038	1.734	0.137	0.310	0.002	0.077	0.414	0.060
Austria	0.694	1.036	1.731	0.089	0.362	0.000	0.023	0.514	0.012
Belgium	0.592	0.884	1.476	0.230	0.213	0.000	0.037	0.432	0.088
Canada	0.655	0.977	1.632	0.191	0.264	0.012	0.122	0.277	0.134
Denmark	0.682	1.017	1.699	0.172	0.278	0.023	0.128	0.286	0.114
Finland	0.636	0.950	1.586	0.189	0.259	0.037	0.141	0.239	0.136
France	0.561	0.838	1.399	0.169	0.292	0.000	0.044	0.430	0.064
Germany	0.576	0.859	1.435	0.181	0.272	0.000	0.063	0.397	0.087
Greece	0.451	0.673	1.125	0.209	0.192	0.001	0.115	0.335	0.149
Ireland	0.699	1.044	1.743	0.199	0.217	0.008	0.142	0.271	0.164
Italy	0.541	0.807	1.348	0.216	0.174	0.007	0.170	0.228	0.205
Japan	0.539	0.805	1.344	0.251	0.164	0.000	0.096	0.330	0.160
Netherlands	0.677	1.010	1.687	0.177	0.267	0.006	0.111	0.321	0.117
New Zealand	0.521	0.777	1.298	0.141	0.310	0.002	0.075	0.410	0.062
Norway	0.896	1.337	2.233	0.123	0.352	0.003	0.072	0.407	0.044
Portugal	0.386	0.575	0.961	0.201	0.245	0.011	0.131	0.261	0.152
Spain	0.479	0.715	1.194	0.232	0.181	0.000	0.000	0.586	0.001
Sweden	0.732	1.093	1.825	0.160	0.283	0.041	0.136	0.284	0.096
Switzerland	0.714	1.065	1.779	0.168	0.286	0.002	0.084	0.370	0.091
United Kingdom	0.634	0.946	1.579	0.174	0.264	0.016	0.129	0.295	0.123
United States	0.799	1.192	1.991	0.197	0.238	0.023	0.146	0.238	0.158

Notes: y^L, y^M, and y^H denote 0.67, 1, and 1.67 times the average earnings in the corresponding country. We categorize the earnings in these three groups so that we can apply the progressive earning tax and replacement rates for these three groups. κ_i^L, κ_i^H, and κ_i^M denote the fraction of population with gender i and earning level less than or equal to y^L, more than y^H, and in between y^L and y^H in the corresponding country, where $i \in \{f, m\}$. Note that $\sum_i \sum_j \kappa_i^j = 1$, that is the measure of the population is normalized to 1. For the detailed explanation of the calculations, see Section 9. Data source: OECD Statistics.

9 Appendix

OECD Statistics provide data on tax rates and replacement rates for three earning groups in each country. Those earning groups are 0.67, 1, and 1.67 times average earnings in the corresponding country. We would like to reflect this fact in the model, because it is an important determinant of the value of employment and unemployment. In order to incorporate this fact into the model properly, we need to determine the distribution of population with respect to gender and earning groups. We approximate this distribution for each country by the following steps:

- Calculating average earnings (comparable across countries):
  - We obtain the ratio of average earnings of women over men for each country k, r^k, from OECD. We set $\tilde{y}_f^k = r$, and $\tilde{y}_m^k = 1$.
  - For each country k, we define $\bar{y}_f^k = \tilde{y}_f^k * gdp^k$, and $\bar{y}_m^k = \tilde{y}_m^k * gdp^k$, which are cross-country comparable average earnings of women and men for each country. gdp^i denotes GDP per capita for country i, comparable across countries, OECD average equals 1.
- Calculating fractions of earning-gender groups in each country k (κ_i^{jk}), where $i \in \{f, m\}$, and $j \in \{L, M, H\}$. L stands for low, M stands for medium and H stands for high earning group:
  - We assume earnings of women and men in country k are distributed normally: $y_i^k \sim N(\bar{y}_i^k, \sigma_{y_i^k})$, where $i \in \{f, m\}$.
  - We need to know $\sigma_{y_f^k}$ and $\sigma_{y_m^k}$ in order to figure out fractions κ_i^{jk}.
  - OECD provides coefficient of variation for the earnings of the whole working population. We assume that the coefficient of variation for women and men

equal to this reported value. Since, we assume the following equalities: $CV_f^k = CV_m^k = CV^k = \sigma_{y_f^k}/\bar{y}_f^k = \sigma_{y_m^k}/\bar{y}_m^k$.

- We extract $\sigma_{y_f^k}$, and $\sigma_{y_m^k}$ from the above equalities.
- Once we have $\bar{y}_f^k$, $\bar{y}_m^k$, $\sigma_{y_f^k}$, and $\sigma_{y_m^k}$, we can calculate $P_i^{Lk} = P(y_i^k < y^{Lk})$, $P_i^{Hk} = P(y_i^k > y^{Hk})$, and $P_i^{Mk} = P(y^{Lk} < y_i^k < y^{Hk})$ for each $i \in \{f, m\}$ under the assumption of normal distribution.
- The fractions for each country k, κ_i^{jk}, can be calculated by multiplying each P_i^{jk} by $L_i^k/(L_i^k + L_{-i}^k)$ which weights each gender by their labor force participation rates, and normalizes the measure of population to 1. (Note that we implicitly assume population have equal number of women and men.)