For Online Publication

Supplementary Appendix for:
Fiscal Externalities and Optimal
Unemployment Insurance

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C Introduction

In this supplementary online appendix, I present additional results from both the structural model and the Baily (1978) model. I begin with two appendices relating to the structural analysis: appendix D describes the method of calibration and presents the moments and parameters used, while appendix E presents numerical results from sensitivity analyses. Subsequently, two appendices provide information which is relevant to both models: appendix F provides more detail about the calibration of the tax system, particularly the estimation of the marginal and average tax rates used in the paper, while appendix G summarizes and discusses empirical sources from the various literatures that study effects of UI on job characteristics.

The remaining sections of this appendix contain the additional results from the sufficient statistics analysis of the Baily model. Appendix H presents proofs and additional algebra for the analysis of the Baily model in section 3 of the paper, while appendix I describes the method of statistical extrapolation used, and appendix J discusses second-order conditions. Appendix K contains the results to numerous sensitivity analyses, and appendix L presents the baseline values of the welfare derivative $\frac{dW}{db}$. Finally, appendix M presents an extensive series of analytical results to complement the numerical results in the paper, and appendix N analyses a series of extensions to the baseline model, to further demonstrate the robustness of my results.

References to numbered equations, tables, etc. not found in this appendix refer to the numbers from the main paper. I begin this online appendix with section C to avoid confusion with appendices A and B in the main paper.

D Technical Appendix for Structural Calibration

D.1 Baseline Case without Wage Effects

To numerically solve the model for any given set of parameters and a value of b, I begin by making a guess for the tax rate and performing value function iteration: an initial guess is chosen for the value functions, and the maximization problem is solved for a range of asset values, which then provides a new guess for the value functions. This process is repeated until the value functions converge, and I only evaluate the maximization problem for a subset of the asset value grid on each iteration, and then use cubic spline interpolation to fill in intermediate points of the value functions, as done by Lentz (2009). Next, the transition process of agents between states is iterated to calculate the steady-state distribution. I then evaluate the government budget surplus, and then re-set the tax rate and repeat the above steps until the budget is balanced, except in the baseline where I know the tax rate is $\tau_0 = 0.282$.

In order to calculate E_b^u, the model must be solved at baseline, and again for a different level of b; since the numerical procedure involves discretizing the asset distribution, the results are slightly "lumpy" at high magnification, so I use a replacement rate of $r = 0.56$, and compute the resulting arc elasticity.[1] With both sets of numerical results in hand, I then estimate the moments of interest in the simulated data and compare them to their real-world counterparts. Due to the "lumpiness" of the results, a precise numerical search for the minimum-distance parameters is not feasible; instead, I find values for the parameters that match the moments as closely as is practical. Finally, in each case, once the parameters have been calibrated, I perform a grid search over r to find the optimal level.

Table D.1 displays the parameters used in the baseline $R = 2$ case; in this table, and in all tables in these appendices, I report the annual discount rate ρ instead of the weekly discount factor $\beta = \left(\frac{1}{1+\rho}\right)^{\frac{1}{52}}$. Table D.2 then presents the moments calculated from the simulated data. Meanwhile, Tables D.3 and D.4 present the parameters and moments for $R = 5$. In each case, the upper limit of the asset distribution was chosen so as to not be binding for all relevant cases, while the number of knots in the cubic spline was chosen so that increasing it further made no difference to the results. The spacing of the asset distribution was set at 0.005; if average UI benefits are about \$300 per week, then a 46% replacement rate implies weekly wages of about \$650,

[1]This variation is comparable to that studied in the empirical literature; for example, Addison and Blackburn (2000) estimate a mean replacement rate of 0.44 with a standard deviation of 0.12 in their data.

and the asset distribution spacing corresponds to about \$3.25. Tests were made of all convergence parameters to ensure that further tightening had no non-negligible effect on results.

Table D.1: Calibrated Parameters with $R = 2$

	Fiscal Externality	Benchmark
ρ	0.0105	0.0105
θ	19.5	19.5
κ	0.869	0.8705

Table D.2: Calculated Moments with $R = 2$

	Fiscal Externality	Benchmark
u	0.0539	0.0539
E_b^u	0.2406	0.2406
$\frac{E(c_e)-E(c_u)}{E(c_e)}$	0.1001	0.1001

Table D.3: Calibrated Parameters with $R = 5$

	Fiscal Externality	Benchmark
ρ	0.0433	0.0430
θ	32.2	31.0
κ	0.778	0.827

Table D.4: Calculated Moments with $R = 5$

	Fiscal Externality	Benchmark
u	0.0540	0.0539
E_b^u	0.2408	0.2406
$\frac{E(c_e)-E(c_u)}{E(c_e)}$	0.1000	0.1001

D.2 Parameters and Moments with Finite-Duration Benefits

The process for numerically solving and calibrating the model with finite-duration benefits takes the same basic form as that described above. Tables D.5 and D.6 display the parameters and moments from the finite-duration UI case with $R = 2$ as studied in appendix A.2, while Tables D.7 and D.8 present the parameters and moments with $R = 5$.

Table D.5: Calibrated Parameters with Finite-Duration Benefits & $R = 2$

	Fiscal Externality	Benchmark
ρ	0.0073	0.00737
θ_1	40.4	39.6
κ	0.265	0.2722

Table D.6: Calculated Moments with Finite-Duration Benefits & $R = 2$

	Fiscal Externality	Benchmark
u	0.0539	0.0540
E_b^u	0.2407	0.2405
$\frac{E(c_e)-E(c_u)}{E(c_e)}$	0.1002	0.1000

Table D.7: Calibrated Parameters with Finite-Duration Benefits & $R = 5$

	Fiscal Externality	Benchmark
ρ	0.0506	0.0499
θ_1	12.2	13.25
κ	1.2	1.2
d	-1.278	-1.269

D.3 Parameters and Moments with Wage Effects

The process for numerically solving and calibrating the model when there are effects of UI on wages takes the same basic form as that described above, except

Table D.8: Calculated Moments with Finite-Duration Benefits & $R = 5$

	Fiscal Externality	Benchmark
u	0.0540	0.0541
E_b^u	0.2407	0.2406
$\frac{E(c_e)-E(c_u)}{E(c_e)}$	0.1002	0.1000

that a 2-dimensional cubic spline is used for the interpolation of the value function over assets and wages. Tables D.9 and D.10 display the parameters and moments for $R = 2$, and Tables D.11 and D.12 do the same for the $R = 5$ case.

Table D.9: Calibrated Parameters with Wage Distribution & $R = 2$

	Fiscal Externality	Benchmark
ρ	0.01117	0.01117
θ	9.645	9.645
κ	2	2
d	0.4666	0.4666
$\underline{y}$	0.6603	0.6603
μ	-1.4284	-1.4284
σ	0.4174	0.4174

Table D.10: Calculated Moments with Wage Distribution & $R = 2$

	Fiscal Externality	Benchmark
u	0.0541	0.0540
E_b^u	0.2401	0.2412
$\frac{E(c_e)-E(c_u)}{E(c_e)}$	0.0997	0.0997
E_b^y	0.0161	0.0162
$E(w)$	1.0002	1.0002

Table D.11: Calibrated Parameters with Wage Distribution & $R = 5$

	Fiscal Externality	Benchmark
ρ	0.0520	0.0527
θ	14.953	14.8696
κ	1.4	1.4
d	0.8953	0.8870
$\underline{y}$	0.5214	0.5261
μ	-0.9713	-0.9838
σ	0.3518	0.3563

Table D.12: Calculated Moments with Wage Distribution & $R = 5$

	Fiscal Externality	Benchmark
u	0.0458	0.0457
E_b^u	0.2418	0.2399
$\frac{E(c_e)-E(c_u)}{E(c_e)}$	0.0997	0.1002
E_b^y	0.0154	0.0156
$E(w)$	0.9998	1.0004

E Sensitivity Analyses in the Structural Model

In this appendix, I present results from sensitivity analyses in the structural model. To begin with, as Chetty (2008) states that his results imply a value of about $R = 5$ in the context of unemployment,[2] I have done the calculations again using that value of risk-aversion. The parameters and resulting moments can be found in Tables D.3 and D.4 in online appendix D.1, and the results are displayed in Table E.1. With more risk-averse individuals, optimal UI is more generous, but the effect of fiscal externalities remains dramatic, with the optimal replacement rate dropping from 68% to 39%.

Next, I present the rest of the sensitivity analyses from appendix A again

[2] Chetty (2006) argues that such a parameter must be chosen to be consistent with the context in which it is being considered, and that "empirical studies that have identified large income effects on labor supply for the unemployed" are inconsistent with low values of R.

Table E.1: Optimal Replacement Rates & Welfare Gains with $R = 5$

Scenario	Replacement Rate r	Welfare Gain
Fiscal Externality	0.39	0.01%
Benchmark	0.68	0.08%

for the case of $R = 5$. The results from the alternative fiscal calibrations can be found in Table E.2, where again the effects of modifications are modest except when a marginal tax rate of 12.1% is used; in the latter case the effect of fiscal externalities on the optimal r drops to 0.12. The rest of the sensitivity analyses can be found in Table E.3, and once again the effect of fiscal externalities on optimal policy remains strong in each case. At the end of the table, I add the results of analyses with intermediate values of R, and it appears that a risk-aversion coefficient just above two is sufficient to eliminate the zero-optimal-UI result.

Table E.2: Fiscal Sensitivity Analyses with $R = 5$

(τ_0, ATR, τ_b)	Scenario	Rep. Rate r	Welfare Gain
No Social Insurance Taxes	Fiscal Externality	0.52	0.004%
$(0.187, 0.026, 0.17)$	Benchmark	0.72	0.10%
5.5% Federal ART	Fiscal Externality	0.38	0.01%
$(0.282, 0.070, 0.17)$	Benchmark	0.68	0.07%
2.9% Social Insurance Tax	Fiscal Externality	0.47	0.0002%
$(0.216, 0.055, 0.17)$	Benchmark	0.70	0.09%
$L = 0$	Fiscal Externality	0.62	0.04%
$(0.121, 0.121, 0.121)$	Benchmark	0.74	0.13%
Drop High Wages	Fiscal Externality	0.44	0.001%
$(0.247, 0.122, 0.142)$	Benchmark	0.69	0.09%

In appendix A.2, I considered finite-duration UI benefits with $R = 2$; Tables D.7 and D.8 contain the parameters and moments for the case in which $R = 5$, while Table E.4 presents the optimal policy results. With the functional form for the effort cost of search from the paper, the upper limit on search

Table E.3: Model Parameter Sensitivity Analyses with $R = 5$

	Scenario	Rep. Rate r	Welfare Gain
$(1+i)^{52} = 0.03$	Fiscal Externality	0.00	0.28%
	Benchmark	0.23	0.05%
$\delta = \frac{1}{364}$	Fiscal Externality	0.40	0.01%
	Benchmark	0.67	0.08%
$E_b^u = 0.1362$	Fiscal Externality	0.58	0.01%
	Benchmark	0.81	0.15%
$E_b^u = 0.3633$	Fiscal Externality	0.26	0.07%
	Benchmark	0.58	0.03%
perfect take-up	Fiscal Externality	0.41	0.01%
	Benchmark	0.62	0.05%
$u = 0.07$	Fiscal Externality	0.37	0.01%
	Benchmark	0.66	0.08%
consumption drop	Fiscal Externality	0.64	0.09%
	Benchmark	0.85	0.43%
utility from leisure	Fiscal Externality	0.40	0.01%
	Benchmark	0.68	0.07%
2 types	Fiscal Externality	0.94	0.84%
	Benchmark	1.08	1.58%
$R = 2.5$	Fiscal Externality	0.02	0.17%
	Benchmark	0.41	0.002%
$R = 3$	Fiscal Externality	0.11	0.12%
	Benchmark	0.48	0.0004%

becomes significantly binding with $R = 5$, so I use a different functional form for the effort cost of search, specifically $e_t(s) = d - \theta_t \left(\frac{(1-s)^{1-\kappa}}{1-\kappa} + s - \frac{1}{1-\kappa} \right)$, where d is a constant; this ensures that s is bounded between 0 and 1. The optimal replacement rates are somewhat lower, as this calibration does not generate as many long-duration unemployment spells; however, the effect of fiscal externalities is quantitatively similar.

Appendix A.3 presented a case in which G was set endogenously to maximize social welfare, and the results for this case when $R = 5$ can be found in Table E.5. The calibrated value of α in this case in 0.2410, and the optimal G

Table E.4: Optimal Replacement Rates & Welfare Gains with Finite-Duration Benefits & $R = 5$

Scenario	Replacement Rate r	Welfare Gain
Fiscal Externality	0.30	0.04%
Benchmark	0.55	0.01%

increases to 0.1036, but the optimal replacement rates are again unaffected.

Table E.5: Optimal Replacement Rates & Welfare Gains with Endogenous G & $R = 5$

Scenario	Replacement Rate r	Welfare Gain
Fiscal Externality	0.39	0.01%
Benchmark	0.68	0.08%

I can also produce results allowing for transitional dynamics, as in appendix A.4, and the results are displayed in Table E.6. Once again, the optimal replacement rates are larger, but the effect of fiscal externalities remains strong.

Table E.6: Optimal Replacement Rates & Welfare Gains with Transitional Dynamics & $R = 5$

Scenario	Replacement Rate r	Welfare Gain
Fiscal Externality	0.69	0.16%
Benchmark	0.89	0.60%

Finally, an analysis in appendix B.1 of the paper shows that, when $R = 2$, a significant effect of UI on subsequent wages can dramatically raise optimal replacement rates, particularly in the fiscal externality scenario; this increase is sufficient to overturn the baseline result and lead to higher optimal UI with fiscal externalities. I can also show that similarly dramatic results follow when $R = 5$. In this case, I was unable to simultaneously calibrate the model to an unemployment rate as high as 5.4% and a wage elasticity as low as

0.0157, so I instead set the target for u at 0.046, which was the average unemployment rate for high-school graduates during 1993-2007 (dropping some high-unemployment years); Tables 9 and E.3 demonstrated that the baseline results were insensitive to the unemployment rate. Tables D.11 and D.12 in supplementary appendix D.3 display the calibrated parameters and moments, and Table E.7 presents the optimal replacement rates. As before, allowing for a positive effect on wages significantly alters the results, with much higher optimal replacement rates which are now equal in the benchmark and fiscal externality scenarios. Taken together, these findings indicates that optimal UI results are strongly sensitive to the effect of UI on wages, and that further empirical work would be beneficial in determining whether or not we should in fact be ignoring this mechanism.

Table E.7: Optimal Replacement Rates & Welfare Gains with Wage Effects & $R = 5$

Scenario	Replacement Rate r	Welfare Gain
Fiscal Externality	0.93	0.51%
Benchmark	0.93	0.40%

F Details on Calibration of Tax System

As described in section 2.2 of the paper, a variety of sources are used to estimate the tax rates relevant to UI recipients. Average tax rates are taken from publications by the Congressional Budget Office and the Institute on Taxation & Economic Policy, as described in the paper. To calculate the marginal income tax rate applying to the typical UI recipient, I use a sample of workers from the 2008 March CPS (Flood et al., 2015); this sample consists of 1825 individuals aged 18 to 64, omitting individuals in the armed forces, those with no UI and those with supplemental and/or strike benefits, and those with no more than one week of unemployment in 2007. I then construct the tax system facing each individual, both at the federal and state level, accounting for their marital status and number of children and using the rules for federal and state income taxes and the EITC in existence in 2007, and I average across the sample using March Supplement weights. I thus calculate the marginal income tax rate faced by the average UI recipient at the federal and state levels, as well as the average EITC subsidy or tax rate. I also identify states which apply income taxation to UI benefits to calculate the average UI tax rate across all individuals.

For the social insurance taxes, I use the 9.5% tax rate reported by the Congressional Budget Office as both the average and marginal rate; estimates in Cushing (2005) indicate that the net marginal social insurance tax rate is indeed approximately 9.5%, adjusting for marginal benefits in the form of expected retirement and disability benefits. I focus on 35- and 40-year-olds, to match the average age of 37 for UI recipients in the SIPP sample of Chetty (2008), and I use the estimates for "middle-income" individuals without Social Security dependents; "middle-income" is a vast group containing 75% of men and 55% of women retiring at age 65 in 2000, who face a 32% marginal Social Security retirement benefit rate. The majority of individuals outside this group are at the 15% marginal benefit rate, facing an even higher net marginal tax rate.[3] Averaging Cushing's results for middle-income 35- and 40-year-olds, I find a net marginal OASDI tax rate of 5.1% to 8.6% for men and 3.3% to 7.7% for women, depending on the discount rate. Adding the 2.9% Medicare

[3]Net marginal tax rates are lower for the lowest income category, but the maximum income for this category was $680 per month in 2007. Such individuals are unlikely to receive UI benefits; only 38 of the 1825 individuals in my CPS sample earned less than $680 per month of employment in 2007.

tax rate, which Cushing ignores as it gives rise to no marginal benefits, the estimated net marginal social insurance tax is 8.0% to 11.5% for men and 6.2% to 10.6% for women, making 9.5% a simple estimate of this tax rate.

To calibrate L, I use the fact that, in the fiscal externality scenario, the average "income" received is $(1-u)y+ub_n$, where $b_n \equiv \frac{b}{(1-\tau_b)}$ is the before-tax value of UI, whereas the after-tax income is $(1-\tau)(1-u)y+ub+L$; accounting for the fact that $y=1$, and using ATR to denote the average tax rate, this implies that:

$$L = \tau(1-u) + \tau_b u b_n - ATR((1-u) + ub_n).$$

Given that the target unemployment rate in the calibration is 0.054, this gives a value of $L = 0.1529$; at the calibrated parameters described in section 2.2, the remainder of the tax revenues implies $G = 0.1032$ for the exogenous government spending.

G Discussion of Effects of UI on Wages & Other Job Characteristics

Table G.1 summarizes the empirical literature that estimates the effect of UI benefit generosity on subsequent wages.[4] The more recent literature has tended to indicate small or zero effects of UI on wages.

A number of papers also address related questions. First of all, several papers estimate effects of UI benefits on wages, but without arriving at a

[4]None of the papers listed report coefficients in the form of an elasticity, so their coefficients have been transformed into approximate elasticities using mean values of wages and benefit levels. Classen (1977) and Holen (1977) do not provide summary statistics, so I use mean values from Burgess and Kingston (1976), who use a smaller version of the dataset used by Holen (1977). Additionally, the estimate listed for Meyer (1989) is from one of 10 individual regressions; the author does not designate a preferred estimate, so the basic difference-in-differences is used.

Table G.1: Results of Empirical Literature on Benefit Elasticity of Wages

Paper	Approx. Elasticity	95% Confidence Interval
Ehrenberg and Oaxaca (1976)	0.27 for older men	(0.12,0.43)
	0.06 for older women	(0.03,0.09)
	0.04 for young men	(-0.04,0.12)
	0.02 for young women	(-0.06,0.10)
Burgess and Kingston (1976)	0.45	(0.26,0.64)
Classen (1977)	0.03	(-0.16,0.21)
Holen (1977)	0.64	(0.55,0.72)
Meyer (1989)	-0.17	(-1.03,0.69)
Maani (1993)*	0.11	(0.02,0.20)
Addison and Blackburn (2000)	-0.05	(-0.14,0.05)

Note: Maani (1993) uses data from New Zealand; all other papers in this table use American data.

simple estimate that can be used in my analysis. Blau and Robins (1986) find a moderately large but not significant effect of UI benefits on the wage offer distribution, plus a positive effect of UI on reservation wages; Fitzenberger and Wilke (2010) perform a Box-Cox quantile regression and do not arrive at a single estimate; and McCall and Chi (2008) find an initial elasticity of 0.10 which declines over the spell of unemployment.

A number of papers have also evaluated the effect of UI benefit duration on wages. Chetty (2008) focusses on two recent papers, Card, Chetty and Weber (2007) and van Ours and Vodopivec (2008), which use natural-experiment methodologies to test for an effect of the potential duration of unemployment benefits on wages, using European data (from Austria and Slovenia respectively), and which find no significant effects.[5] Additionally, Gaure, Røed and Westlie (2012) and Nekoei and Weber (2017) find a positive effect of benefit durations on wages, while Lalive (2007) and Schmieder, von Wachter and Bender (2016) do not (the latter paper finds a negative effect). Finally, Cen-

[5]These findings are at least suggestive, but may not be definitive in a North American context, given the different labour market structures and institutions found in Europe, such as higher union coverage, as acknowledged by Card, Chetty and Weber (2007).

teno (2004), Centeno and Novo (2006), and Tatsiramos (2009) find that more generous UI leads to greater subsequent job duration, whereas Portugal and Addison (2008) do not. The papers summarized in this appendix, therefore, lead to a conclusion about the effect of UI on wages and other job characteristics that is thoroughly ambiguous.

However, the analysis in appendix B demonstrates that even a relatively small effect of UI on wages could be sufficient to offset the negative fiscal externalities from lengthened unemployment durations. For the structural analysis, I use estimates derived from Nekoei and Weber (2017) to produce a central estimate of the effects of UI on wages. That paper finds that a 9-week increase in potential UI duration in Austria raises wages by 0.45% and unemployment durations by 1.67% (a 1.9 day increase from an average base of 114 days); I therefore want an elasticity of wages on new jobs that is $\frac{0.45}{1.67} = 26.9\%$ as large as the elasticity of unemployment durations, but I need an estimate of the fraction of total employment represented by "new" jobs. In my sufficient statistics analysis, I use a central estimate of $s_0 = 0.8$, which implies that someone who loses their job would spend 20% of the second period unemployed, and which implies a job loss probability of $\delta = 0.54$; then the total amount of expected time spent on a new job is 0.432, and with 1.46 units of time spent on the old job, this implies that $\frac{0.432}{1.892} = 22.8\%$ of total employment is spent on "new" jobs that can be affected by UI. Therefore, I take as my central estimate a value of $\frac{d\ln(E(y))}{d\ln(b)} = \frac{0.432}{1.892}\frac{0.45}{1.67}0.2544 = 0.0157$. In the sufficient statistics analysis, given the greater computational simplicity, I provide estimates for the range of values covered by Table G.1.

H Proofs and Algebra

H.1 Proof of Proposition 1

The individual's first-order condition for saving is:

$$\frac{\partial V}{\partial k} = -U'(c_1) + (1-\delta)U'(c_e) + \delta U'(c_u) = 0$$

and I also use a first-order Taylor series expansion of $U'(c_1)$ around $U'(c_u)$:

$$U'(c_1) = U'(c_u) + \Delta c U''(\theta)$$

where θ is between c_u and c_1, and $\Delta c = c_1 - c_u$. Combining these allows me to rewrite (5) as:

$$\frac{dV}{db} = -2y\Delta c U''(\theta)\frac{d\tau}{db} - \left[(2-\delta)y + \delta s y_n\right] U'(c_u)\left[\frac{d\tau}{db} - \omega\right]$$

where $\omega = \frac{\delta(1-s)}{(2-\delta)y+\delta s y_n}$.

Next, I make two assumptions that are also found in Baily (1978); they are listed in section 3.1 as Assumptions 1 and 2. The first is that the wage distribution is degenerate with $y_n = y$, so all wages can be written in terms of y. The second assumption is that $c_1 U''(\theta) = c_u U''(c_u)$, which permits the second derivative of utility to be incorporated into a coefficient of relative risk-aversion. The validity of this assumption depends on the functional form of utility and on the magnitude of risk-aversion; in general it can only be an approximation. If I assume constant relative risk-aversion, then for my baseline risk-aversion coefficient of 2, this assumption will tend to overstate the consumption smoothing benefit implied by $U''(\theta)$ – that is, $-c_1 U''(\theta) < -c_u U''(c_u)$ – and therefore the estimated optimal replacement rate will be too high. However, simulations (available upon request) confirm that it is much more accurate than the usual assumption of $U'(c_1) = U'(c_u) + \Delta c U''(c_u)$.

Combining these two assumptions, and dividing by $U'(c_u)$ to put the welfare derivative in dollar terms, I find:

$$\frac{dW}{db} \equiv \frac{\frac{dV}{db}}{U'(c_u)} = 2y\frac{\Delta c}{c_1}R\frac{d\tau}{db} - 2(1-u)y\left[\frac{d\tau}{db} - \omega\right] \tag{H.1}$$

where $R = \frac{-c_u U''(c_u)}{U'(c_u)}$ is the coefficient of relative risk-aversion, and $u = \frac{\delta(1-s)}{2}$ is the unemployment rate. At the optimum, $\frac{dW}{db} = 0$, and this will be a unique optimum if W is strictly quasi-concave; thus, the expression for the optimum is:

$$\frac{\Delta c}{c_1}R = (1-u)\frac{\frac{d\tau}{db} - \omega}{\frac{d\tau}{db}}.$$

Using elasticities, the marginal value of increased benefits is also equal to:

$$\frac{dW}{db} = \frac{2u}{(1-u)\psi}\left[\frac{\Delta c}{c_1}RE_b^\tau - (1-u)\left(E_b^\tau - \psi\right)\right] \tag{H.2}$$

where $E_b^\tau = \frac{b}{\tau}\frac{d\tau}{db}$ is the elasticity of τ with respect to b, and $\psi = \frac{\omega b}{\tau} = \frac{ub}{ub+P}$ is the fraction of total government expenditures allocated to UI; set equal to zero, this gives the following expression for the optimum:

$$\frac{\Delta c}{c_1}R = (1-u)\frac{E_b^\tau - \psi}{E_b^\tau}.$$

In section 3.2, this result is combined with the derivative of the government budget constraint to arrive at equation (14). In the latter, we can notice that the above expression depends on the size of government only through ψ, which itself depends only on P and not the division of P into G and L; this reinforces the finding from sensitivity analyses on the structural model that results are not sensitive to the average tax rate.

H.2 Algebraic Analysis of $\frac{dW}{db}$

In order to prove that $\frac{dW}{db}$ increases with P if and only if E_b^D is negative, (H.2) can also be written as:

$$\frac{dW}{db}(b;P) = \frac{2u}{1-u}\left[\frac{\Delta c}{c_1}R\frac{E_b^\tau}{\psi} - (1-u)\left(\frac{E_b^\tau}{\psi} - 1\right)\right]$$

and therefore we can compare the welfare derivatives when two different values of P are used, 0 and $P > 0$:

$$\frac{dW}{db}(b;P) - \frac{dW}{db}(b;0) = \frac{2u}{1-u}\left[\frac{\Delta c}{c_1}R - (1-u)\right]\left[\left(\frac{E_b^\tau}{\psi}\right)_{P>0} - \left(\frac{E_b^\tau}{\psi}\right)_{P=0}\right].$$

Using (13) and the definition of ψ:

$$\frac{E_b^\tau}{\psi} = 1 + E_b^D + \frac{ub+P}{ub}\left[\frac{\delta(1-s)}{2(1-u)}E_b^D\right]$$

and thus the welfare derivative difference becomes:

$$\frac{dW}{db}(b;P) - \frac{dW}{db}(b;0) = \frac{\delta(1-s)}{(1-u)^2 b}\left[\frac{\Delta c}{c_1}R - (1-u)\right]E_b^D P.$$

I now assume that $\frac{\Delta c}{c_1}R < 1-u$, and therefore the right-hand side will be positive if and only if E_b^D is negative.

I Summary of Statistical Extrapolation Procedure

In this appendix, I describe the procedure of statistical extrapolation used to numerically evaluate (14) or (16) to find the optimal benefit level; further detail is provided by the description of the method in Chetty (2009). First of all, the optimal UI literature overwhelmingly solves for an optimal replacement rate rather than a dollar value of UI, so as in the structural analysis earlier, I will do the same. As before, I define the replacement rate as $r = \frac{b}{(0.8)\left(\frac{15.8}{24.3}\right)(1-\tau_b)}$, where

τ_b is the tax rate applying to UI income, 0.8 is the take-up rate, and $\frac{15.8}{24.3}$ is the ratio of mean compensated unemployment duration to mean total duration. The steps in the procedure used to solve (12) for the optimal replacement rate are as follows:

- select an equation for $\frac{\Delta c}{c_1}$ as a function of r
- select fixed values of E_b^D and R
- select current values of r and u
- use the fixed value of E_b^D to define a functional form for u with respect to r: $u = \phi r^{E_b^D}$, and use the current values of u and r to solve for ϕ
- select the current value of ψ, and specify the relationship of ψ to r
- solve the resulting non-linear equation in r

J Second-Order Conditions

For the optimal UI equation (14) or (16) to identify the unique maximum, strict quasi-concavity is required, and I can test this assumption in my numerical analysis by plotting the estimated value of $\frac{dW}{db}$ at intervals of 0.01 for $r \in [0.01, 2]$, for each set of parameter values, and for the initial model as well as all sensitivity analyses and extensions. I can then see if any failures of quasi-concavity appear over that range; beyond $r = 2$, failures of quasi-concavity might be expected on the grounds that Assumptions 1.A and 2 become especially poor approximations. All plots are available upon request.

For the baseline model, quasi-concavity always appears to be satisfied. However, in the extension to $R = 5$, quasi-concavity fails in several cases in the fiscal externality scenario: for $E_b^y \geq 0.048$, there appears to be a local minimum at low values of r (always less than 0.09). It is not surprising, however, that these violations of strict quasi-concavity occur at low values of r when R is large, as that is exactly when $\frac{\Delta c}{c_1}R < 1 - u$ may fail to hold and my assumptions will tend to be most inaccurate, and at which the estimated E_b^τ could turn negative. Over the vast majority of the range of r that I consider, however, $\frac{dW}{db}$ behaves normally and consistent with quasi-concavity.

In each of the sensitivity analyses in supplementary appendix K, similar local minima are found at low r for $R = 5$ and $E_b^y \geq 0.048$. Further failures of quasi-concavity are observed in each of the extensions in supplementary appendix N; in the first, second, and fourth extensions, local minima are again observed for $R = 5$ and $E_b^y \geq 0.048$. The first extension presents cases for $R = 2$, $E_b^y = 0$ and $s_0 \leq 0.8$ where local maxima are observed at positive values of r but the global maximum is at $r = 0$. Similar cases are observed thrice in the second extension at high values of E_b^y and s_0 for $R = 5$, though as discussed in supplementary appendix N.2, these are anomalous as the optimal replacement rate should logically be close to one. In the third extension, local maxima are also observed for $R = 5$, $E_b^y = 0$, and each s_0, but once again the global maximum is at zero.

K Sensitivity Analyses in the Baily Model

In this appendix, I present results from a number of sensitivity analyses in the sufficient statistics approach. I begin by extending the results in Table 7 to a case of $R = 5$, with results as displayed in Table K.1. The decline in optimal UI due to fiscal externalities is smaller than in the structural model; the difference is generated partly by the fact that E_b^D increases with b in the latter model, whereas it is held fixed during statistical extrapolations, but also because of other differences in the models, such as the fact that the steady-state asset distribution changes with b in the structural model.

Table K.1: Optimal Replacement Rates & Welfare Gains with $R = 5$

Scenario	Replacement Rate r	Welfare Gain
Fiscal Externality	0.5876	0.04%
Benchmark	0.6866	0.12%

Next, I again use $R = 5$ and present results when there may be effects of UI on subsequent wages. Table K.2 presents results analogous to those in Table 14. The numerical results are less extreme than they were for $R = 2$, but the same pattern of findings is present there as well: in the fiscal externality scenario, the optimal replacement rates spread out noticeably, becoming more sensitive to both E_b^y and s.

Table K.2: Optimal Replacement Rates Calculated from (16) for $R = 5$

Optimal r for Benchmark Scenario:					
		s_0			
		0.648	0.725	0.8	0.863
	-0.0816	0.6831	0.6815	0.6787	0.6741
	0	0.6866	0.6866	0.6866	0.6866
E_b^y	0.048	0.6887	0.6897	0.6914	0.6942
	0.096	0.6909	0.6928	0.6962	0.7020
	0.192	0.6951	0.6991	0.7061	0.7183
	0.3072	0.7004	0.7069	0.7184	0.7390
Optimal r for Fiscal Externality Scenario:					
		s_0			
		0.648	0.725	0.8	0.863
	-0.0816	0.5336	0.5100	0.4707	0.4089
	0	0.5876	0.5876	0.5876	0.5876
E_b^y	0.048	0.6192	0.6334	0.6579	0.6993
	0.096	0.6505	0.6790	0.7278	0.8099
	0.192	0.7122	0.7683	0.8638	1.0202
	0.3072	0.7839	0.8714	1.0173	1.2477

I now proceed to a further series of sensitivity results for both $R = 2$

and $R = 5$. First, I use different values of E_b^D over a wide range; I try $E_b^D = 0.48 \times 0.3$, with results in Tables K.3 and K.4, and $E_b^D = 0.48 \times 0.8$, with results in Tables K.5 and K.6. Not surprisingly, the optimal replacement rates move up in the former case and down in the latter; the effects of fiscal externalities remain sizable in both cases. At a value of E_b^D slightly below 0.144, I begin to observe a positive local maximum when $R = 2$ and $E_b^y = 0$; for a positive global maximum, I need E_b^D to drop below 0.1.

Then I try two alternative baseline values of τ_0; in particular, I consider cases with baseline marginal tax rates of 0.15 and 0.35, with results in Tables K.7 and K.8. The results are unsurprising, as a lower value of τ_0 leads to results that are closer to the benchmark scenario, while higher values imply more extreme effects of fiscal externalities.

Next, I ignore the question of take-up of benefits and only deflate benefits by the ratio of compensated to total unemployment duration; the ensuing results can be found in Tables K.9 and K.10. This tends to reduce the size of the difference between optimal replacement rates, but I still observe zeros for $R = 2$ and $E_b^y = 0$.

Finally, I try a larger value of the initial unemployment rate, specifically $u_0 = 0.064$. This leads to the results displayed in Tables K.11 and K.12. The optimal replacement rates spread out in the benchmark scenario, but the effects are more modest in the fiscal externality scenario, meaning a small reduction in the effect of fiscal externalities.

L Baseline Values of $\frac{dW}{db}$

Equation (H.2), when combined with (15), provides a way of evaluating $\frac{dW}{db}$, as in Chetty (2008), although a direct comparison to that paper is limited by

Table K.3: Optimal Replacement Rates for $R = 2$ and $E_b^D = 0.144$

Optimal r for Benchmark Scenario:					
		s_0			
		0.648	0.725	0.8	0.863
	-0.0816	0.5908	0.5859	0.5776	0.5637
	0	0.6020	0.6020	0.6020	0.6020
E_b^y	0.048	0.6087	0.6116	0.6167	0.6254
	0.096	0.6154	0.6213	0.6317	0.6494
	0.192	0.6289	0.6411	0.6624	0.6997
	0.3072	0.6454	0.6653	0.7007	0.7640
Optimal r for Fiscal Externality Scenario:					
		s_0			
		0.648	0.725	0.8	0.863
	-0.0816	0	0	0	0
	0	0	0	0	0
E_b^y	0.048	0.5193	0.5783	0.6640	0.7851
	0.096	0.6423	0.7300	0.8596	1.0460
	0.192	0.8230	0.9573	1.1580	1.4483
	0.3072	0.9943	1.1749	1.4443	1.8288

Table K.4: Optimal Replacement Rates for $R = 5$ and $E_b^D = 0.144$

Optimal r for Benchmark Scenario:					
		s_0			
		0.648	0.725	0.8	0.863
	-0.0816	0.7391	0.7371	0.7338	0.7283
	0	0.7435	0.7435	0.7435	0.7435
E_b^y	0.048	0.7461	0.7473	0.7493	0.7528
	0.096	0.7487	0.7511	0.7552	0.7623
	0.192	0.7540	0.7589	0.7675	0.7824
	0.3072	0.7606	0.7686	0.7828	0.8081
Optimal r for Fiscal Externality Scenario:					
		s_0			
		0.648	0.725	0.8	0.863
	-0.0816	0.6160	0.5885	0.5428	0.4713
	0	0.6795	0.6795	0.6795	0.6795
E_b^y	0.048	0.7172	0.7342	0.7635	0.8133
	0.096	0.7551	0.7893	0.8484	0.9483
	0.192	0.8307	0.8992	1.0165	1.2103
	0.3072	0.9203	1.0283	1.2095	1.4972

Table K.5: Optimal Replacement Rates for $R = 2$ and $E_b^D = 0.384$

Optimal r for Benchmark Scenario:					
		s_0			
		0.648	0.725	0.8	0.863
E_b^y	-0.0816	0.3129	0.3096	0.3039	0.2943
	0	0.3213	0.3213	0.3213	0.3213
	0.048	0.3262	0.3283	0.3317	0.3376
	0.096	0.3312	0.3352	0.3422	0.3541
	0.192	0.3411	0.3493	0.3636	0.3882
	0.3072	0.3531	0.3664	0.3897	0.4310
Optimal r for Fiscal Externality Scenario:					
		s_0			
		0.648	0.725	0.8	0.863
E_b^y	-0.0816	0	0	0	0
	0	0	0	0	0
	0.048	0.0252	0.0525	0.1397	0.3005
	0.096	0.1431	0.2498	0.3908	0.5608
	0.192	0.3694	0.4897	0.6534	0.8712
	0.3072	0.5263	0.6668	0.8653	1.1349

Table K.6: Optimal Replacement Rates for $R = 5$ and $E_b^D = 0.384$

Optimal r for Benchmark Scenario:					
		s_0			
		0.648	0.725	0.8	0.863
E_b^y	-0.0816	0.6292	0.6279	0.6256	0.6219
	0	0.6320	0.6320	0.6320	0.6320
	0.048	0.6337	0.6345	0.6359	0.6382
	0.096	0.6354	0.6370	0.6398	0.6445
	0.192	0.6389	0.6421	0.6478	0.6576
	0.3072	0.6430	0.6483	0.6576	0.6741
Optimal r for Fiscal Externality Scenario:					
		s_0			
		0.648	0.725	0.8	0.863
E_b^y	-0.0816	0.4557	0.4353	0.4012	0.3475
	0	0.5029	0.5029	0.5029	0.5029
	0.048	0.5301	0.5421	0.5627	0.5973
	0.096	0.5567	0.5805	0.6211	0.6887
	0.192	0.6082	0.6544	0.7322	0.8586
	0.3072	0.6669	0.7378	0.8551	1.0392

Table K.7: Optimal Replacement Rates for $R = 2$

Optimal r for $\tau_0 = 0.15$:					
		s_0			
		0.648	0.725	0.8	0.863
E_b^y	-0.0816	0	0	0	0
	0	0	0	0	0
	0.048	0.3070	0.3591	0.4242	0.5077
	0.096	0.4118	0.4728	0.5578	0.6743
	0.192	0.5370	0.6212	0.7433	0.9157
	0.3072	0.6457	0.7544	0.9143	1.1413
Optimal r for $\tau_0 = 0.35$:					
		s_0			
		0.648	0.725	0.8	0.863
E_b^y	-0.0816	0	0	0	0
	0	0	0	0	0
	0.048	0.0255	0.1406	0.3641	0.5380
	0.096	0.3386	0.4697	0.6291	0.8329
	0.192	0.5888	0.7369	0.9448	1.2309
	0.3072	0.7741	0.9575	1.2214	1.5859

Table K.8: Optimal Replacement Rates for $R = 5$

Optimal r for $\tau_0 = 0.15$:					
		s_0			
		0.648	0.725	0.8	0.863
E_b^y	-0.0816	0.6052	0.5918	0.5692	0.5318
	0	0.6349	0.6349	0.6349	0.6349
	0.048	0.6523	0.6603	0.6739	0.6969
	0.096	0.6697	0.6855	0.7128	0.7589
	0.192	0.7041	0.7358	0.7899	0.8806
	0.3072	0.7449	0.7950	0.8800	1.0193
Optimal r for $\tau_0 = 0.35$:					
		s_0			
		0.648	0.725	0.8	0.863
E_b^y	-0.0816	0.4983	0.4700	0.4239	0.3549
	0	0.5641	0.5641	0.5641	0.5641
	0.048	0.6027	0.6201	0.6500	0.7006
	0.096	0.6410	0.6757	0.7352	0.8351
	0.192	0.7161	0.7843	0.8999	1.0877
	0.3072	0.8029	0.9084	1.0831	1.3555

Table K.9: Optimal Replacement Rates for $R = 2$ and Perfect Take-Up

Optimal r for Benchmark Scenario:					
		s_0			
		0.648	0.725	0.8	0.863
E_b^y	-0.0816	0.4500	0.4459	0.4390	0.4275
	0	0.4595	0.4595	0.4595	0.4595
	0.048	0.4651	0.4675	0.4717	0.4789
	0.096	0.4707	0.4756	0.4842	0.4987
	0.192	0.4821	0.4921	0.5095	0.5399
	0.3072	0.4959	0.5122	0.5410	0.5922
Optimal r for Fiscal Externality Scenario:					
		s_0			
		0.648	0.725	0.8	0.863
E_b^y	-0.0816	0	0	0	0
	0	0	0	0	0
	0.048	0.0326	0.2874	0.4001	0.5203
	0.096	0.3821	0.4715	0.5878	0.7413
	0.192	0.5591	0.6704	0.8287	1.0487
	0.3072	0.7007	0.8410	1.0444	1.3288

Table K.10: Optimal Replacement Rates for $R = 5$ and Perfect Take-Up

Optimal r for Benchmark Scenario:					
		s_0			
		0.648	0.725	0.8	0.863
E_b^y	-0.0816	0.6831	0.6815	0.6787	0.6741
	0	0.6866	0.6866	0.6866	0.6866
	0.048	0.6887	0.6897	0.6914	0.6942
	0.096	0.6909	0.6928	0.6962	0.7020
	0.192	0.6951	0.6991	0.7061	0.7183
	0.3072	0.7004	0.7069	0.7184	0.7390
Optimal r for Fiscal Externality Scenario:					
		s_0			
		0.648	0.725	0.8	0.863
E_b^y	-0.0816	0.5638	0.5444	0.5118	0.4591
	0	0.6076	0.6076	0.6076	0.6076
	0.048	0.6332	0.6447	0.6646	0.6983
	0.096	0.6586	0.6817	0.7215	0.7884
	0.192	0.7088	0.7547	0.8329	0.9621
	0.3072	0.7676	0.8395	0.9603	1.1536

Table K.11: Optimal Replacement Rates for $R = 2$ and $u_0 = 0.064$

Optimal r for Benchmark Scenario:					
		s_0			
		0.648	0.725	0.8	0.863
	-0.0816	0.4491	0.4443	0.4362	0.4227
	0	0.4603	0.4603	0.4603	0.4603
E_b^y	0.048	0.4670	0.4698	0.4748	0.4833
	0.096	0.4736	0.4794	0.4895	0.5069
	0.192	0.4871	0.4989	0.5198	0.5562
	0.3072	0.5034	0.5228	0.5574	0.6195
Optimal r for Fiscal Externality Scenario:					
		s_0			
		0.648	0.725	0.8	0.863
	-0.0816	0	0	0	0
	0	0	0	0	0
E_b^y	0.048	0.0281	0.2336	0.3877	0.5314
	0.096	0.3661	0.4737	0.6096	0.7867
	0.192	0.5756	0.7041	0.8859	1.1378
	0.3072	0.7377	0.8984	1.1093	1.4542

Table K.12: Optimal Replacement Rates for $R = 5$ and $u_0 = 0.064$

Optimal r for Benchmark Scenario:					
		s_0			
		0.648	0.725	0.8	0.863
	-0.0816	0.6828	0.6809	0.6777	0.6723
	0	0.6870	0.6870	0.6870	0.6870
E_b^y	0.048	0.6895	0.6906	0.6926	0.6960
	0.096	0.6920	0.6943	0.6984	0.7053
	0.192	0.6971	0.7018	0.7101	0.7247
	0.3072	0.7033	0.7111	0.7249	0.7499
Optimal r for Fiscal Externality Scenario:					
		s_0			
		0.648	0.725	0.8	0.863
	-0.0816	0.5377	0.5146	0.4764	0.4166
	0	0.5905	0.5905	0.5905	0.5905
E_b^y	0.048	0.6216	0.6357	0.6599	0.7009
	0.096	0.6526	0.6807	0.7292	0.8109
	0.192	0.7136	0.7694	0.8646	1.0209
	0.3072	0.7849	0.8721	1.0178	1.2479

the different ways marginal welfare is normalized into dollars; Chetty divides by marginal utility when re-employed, while I divide by $U'(c_u)$. In Tables L.1 and L.2, I present the values of this derivative at the baseline value of $r = 0.46$, for both $R = 2$ and $R = 5$. The results are conceptually similar to those in Tables 14 and K.2, in that a positive value of P causes the values in the table to "spread out."

M Analytical Results

In this appendix, I will further analyze the equations derived in appendix B.2 of the main paper, and specifically I will present a series of analytical results about equations for $\frac{dW}{db}$ and for the optimal level of UI benefits. I will discuss $\frac{dW}{db}(b; P)$, the estimated welfare derivative at a particular value of b given an estimated value of P, and $b^*(P)$, the estimated optimal value of b for a given value of P. I consider how the results change when estimated quantities like P and E_b^y are changed.

It should be emphasized that this is not a comparative statics exercise, as I am not considering a change to a primitive parameter of the model; rather, I consider how the numerical results should be expected to change when the estimated value of P used in the calculations is altered. This represents a change in assumptions about the model, not a change in parameters, and so the values of the sufficient statistics are unaltered, since they reflect the unchanged real world to which the model is calibrated. A helpful thought experiment is that of the "two researchers": one who assumes that the true value of P is zero, and another who has estimated a positive value of P from some real-world data, while they agree on all other sufficient statistics necessary to calculate the optimum. My analysis answers the question: who will estimate a larger

Table L.1: Baseline Values of $\frac{dW}{db}$ Calculated from (H.2) and (15) for $R = 2$

Baseline $\frac{dW}{db}$ for Benchmark Scenario:					
		s_0			
		0.648	0.725	0.8	0.863
E_b^y	-0.0816	-0.0008	-0.0011	-0.0016	-0.0025
	0	-0.0000	-0.0000	-0.0000	-0.0000
	0.048	0.0004	0.0006	0.0009	0.0014
	0.096	0.0008	0.0012	0.0018	0.0029
	0.192	0.0017	0.0024	0.0037	0.0058
	0.3072	0.0027	0.0039	0.0059	0.0094
Baseline $\frac{dW}{db}$ for Fiscal Externality Scenario:					
		s_0			
		0.648	0.725	0.8	0.863
E_b^y	-0.0816	-0.0477	-0.0556	-0.0690	-0.0917
	0	-0.0296	-0.0296	-0.0296	-0.0296
	0.048	-0.0189	-0.0143	-0.0063	0.0070
	0.096	-0.0082	0.0010	0.0169	0.0436
	0.192	0.0132	0.0316	0.0633	0.1167
	0.3072	0.0388	0.0684	0.1190	0.2044

Table L.2: Baseline Values of $\frac{dW}{db}$ Calculated from (H.2) and (15) for $R = 5$

Baseline $\frac{dW}{db}$ for Benchmark Scenario:					
		s_0			
		0.648	0.725	0.8	0.863
E_b^y	-0.0816	0.0430	0.0428	0.0425	0.0420
	0	0.0435	0.0435	0.0435	0.0435
	0.048	0.0437	0.0438	0.0440	0.0443
	0.096	0.0440	0.0442	0.0446	0.0452
	0.192	0.0445	0.0449	0.0457	0.0470
	0.3072	0.0451	0.0458	0.0470	0.0491
Baseline $\frac{dW}{db}$ for Fiscal Externality Scenario:					
		s_0			
		0.648	0.725	0.8	0.863
E_b^y	-0.0816	0.0150	0.0103	0.0023	-0.0113
	0	0.0258	0.0258	0.0258	0.0258
	0.048	0.0322	0.0350	0.0397	0.0477
	0.096	0.0386	0.0441	0.0536	0.0695
	0.192	0.0514	0.0624	0.0813	0.1132
	0.3072	0.0667	0.0843	0.1146	0.1656

optimal b, and by how much?

Throughout this appendix, I maintain two additional assumptions, as in the discussion in subsection 3.2 of the main paper; the first is that $\frac{\Delta c}{c_1}R < 1-u$, and the second is that W (the integral of $\frac{dW}{db}$) is strictly quasi-concave in b. I begin with an analysis of how the results change when I alter the selected value of P. The first result concerns the value of the welfare derivative at a given value of b, and is described in the proposition below.

Proposition 2. *For $P > 0$, $\frac{dW}{db}(b; P) - \frac{dW}{db}(b; 0)$ has the same sign as $sE_b^y - (1-s)E_b^D$, or equivalently the same sign as $\frac{d(sy_n)}{db}$.*

Proof. Starting from (H.2):

$$\frac{dW}{db}(b; P) = \frac{2u}{1-u}\left[\frac{\Delta c}{c_1}R\frac{E_b^\tau}{\psi} - (1-u)\left(\frac{E_b^\tau}{\psi} - 1\right)\right]$$

and therefore the difference in welfare derivatives is:

$$\frac{dW}{db}(b; P) - \frac{dW}{db}(b; 0) = \frac{2u}{1-u}\left[\frac{\Delta c}{c_1}R - (1-u)\right]\left[\left(\frac{E_b^\tau}{\psi}\right)_{P>0} - \left(\frac{E_b^\tau}{\psi}\right)_{P=0}\right].$$

Using (15) and the definition of ψ:

$$\frac{E_b^\tau}{\psi} = 1 + E_b^D + \frac{ub + P}{ub}\left[\frac{\delta(1-s)}{2(1-u)}E_b^D - \frac{\delta s}{2(1-u)}E_b^y\right]$$

and thus the welfare derivative difference becomes:

$$\frac{dW}{db}(b; P) - \frac{dW}{db}(b; 0) = \frac{\delta}{(1-u)^2 b}\left[\frac{\Delta c}{c_1}R - (1-u)\right]\left[(1-s)E_b^D - sE_b^y\right]P.$$

Since I assume that $\frac{\Delta c}{c_1}R < 1-u$, this right-hand side will be positive if and only if $sE_b^y - (1-s)E_b^D$ is positive. The latter expression can also be written as:

$$sE_b^y - (1-s)E_b^D = \frac{sb}{y_n}\frac{dy_n}{db} + b\frac{ds}{db} = \frac{b}{y_n}\frac{d(sy_n)}{db}.$$

and therefore $\frac{dW}{db}(b; P) - \frac{dW}{db}(b; 0)$ has the same sign as $\frac{d(sy_n)}{db}$. □

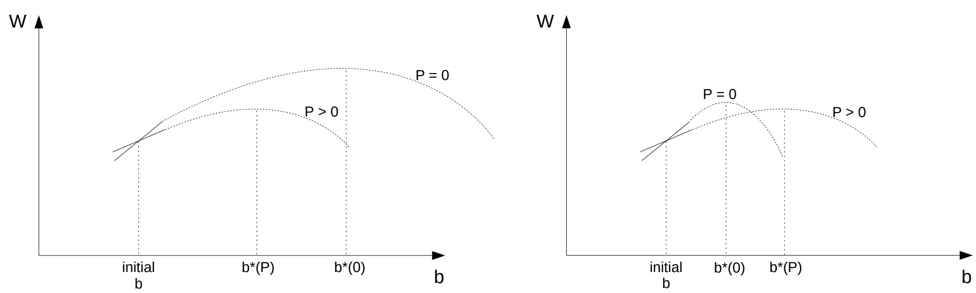
Therefore, if two researchers use (H.2) to estimate the baseline welfare derivative, one using $P = 0$ and the other a positive value of P, the latter will find a larger welfare gain from increasing b if and only if $\frac{d(sy_n)}{db}$ is positive. Ignoring P greatly understates the revenue effects of changing b, and while higher UI is expected to increase durations of unemployment, it may also increase wages. If this wage effect is so large as to lead to an increase in total post-unemployment earnings sy_n, which is the only non-exogenous component of total earnings in the model, the overall revenue effect is positive and welfare-increasing. Therefore, using a positive value of P, which implies higher taxes, amplifies this positive revenue effect and increases the welfare gain from raising benefits. If $\frac{d(sy_n)}{db}$ is negative, the reverse holds.

An immediate corollary arising from quasi-concavity is that, if the baseline welfare derivative is zero for $P = 0$, and thus the current level of b is estimated to be optimal in that case, then the optimum for the true P will be larger or smaller according to the sign of $\frac{d(sy_n)}{db}$. For example, if $\frac{d(sy_n)}{db} > 0$, $\frac{dW}{db}(b; P) > 0$ and quasi-concavity means that the optimum must be found at a higher b. A similar logic applies if $\frac{dW}{db}(b; P) = 0$; if one of the welfare derivatives is zero, I only need to know the other to make a comparison. This result is summarized by the following corollary.

Corollary 1. *If, for the current value of b, $\frac{dW}{db}(b; 0) = 0$ or $\frac{dW}{db}(b; P) = 0$, $b^*(P) > b^*(0)$ if and only if $sE_b^y - (1 - s)E_b^D > 0$, or equivalently if and only if $\frac{d(sy_n)}{db} > 0$.*

Furthermore, if the welfare derivative is of opposite signs for $P = 0$ and $P > 0$, then a comparison of the estimated optimal values of b is simple; if, for example, $\frac{dW}{db}(b; 0) > 0$ and $\frac{dW}{db}(b; P) < 0$, then clearly $b^*(0) > b^*(P)$. For a more general result, however, I need to go beyond the local welfare derivative and make out-of-sample assumptions; as an illustration, consider Figure M.1, which displays graphically how knowledge of a local welfare derivative doesn't permit unambiguous conclusions about the optimum.[6] Chetty (2009) recommends the method of statistical extrapolation that has been used by Baily (1978) and Gruber (1997), in which each sufficient statistic is extrapolated out of sample as described at the end of subsection 3.2 of the paper. For this purpose, I define $\chi = \{\frac{\Delta c}{c_1}, R, s, E_b^D, E_b^y\}$ as the vector of sufficient statistics, the underlying quantities in (16) which are not exogenously fixed, and let $\chi(b)$ denote a particular vector of extrapolated values of these quantities.[7] This leads to the following corollary.

Figure M.1: Two Possible Welfare Functions



Corollary 2. *For statistical extrapolations that do not depend on the estimated value of* P*, i.e.* $\chi(b; P) = \chi(b)$*,* $b^*(P) > b^*(0)$ *if and only if* $sE_b^y - (1-s)E_b^D > 0$*, or equivalently if and only if* $\frac{d(sy_n)}{db} > 0$*, in between* $b^*(0)$ *and* $b^*(P)$*.*

Proof. If a statistical extrapolation is used to find $b^*(0)$, and the same statistical extrapolation is used for the case of $P > 0$, then $\frac{dW}{db}(b^*(0); P)$ takes

[6] The values of W in the diagram are normalized to be equal at the initial b, but while it is clear that $\frac{dW}{db}(b; 0) > \frac{dW}{db}(b; P)$ in the diagram, the dotted lines further to the right are meant to indicate that the sufficient statistics alone give no definite answer about the shape of these curves.

[7] Strict quasi-concavity of W, when the latter is estimated out of sample using statistical extrapolations, implicitly places some restrictions on the extrapolations allowed.

the same sign as $\frac{d(sy_n)}{db}$ at $b^*(0)$. If that sign is positive, then by strict quasi-concavity $b^*(P) > b^*(0)$, and $\frac{d(sy_n)}{db}$ will continue to be positive at least until $b^*(P)$. If the sign is negative, the opposite is true. □

Therefore, if two researchers using $P = 0$ and $P > 0$ use the same statistical extrapolations of the sufficient statistics, then the second researcher's estimated optimal value $b^*(P)$ will be the larger of the two if and only if $\frac{d(sy_n)}{db} > 0$ in between the optimal values of b; the proof explains why the sign of $\frac{d(sy_n)}{db}$ will not change in that region.[8] This is arguably the most important result in this appendix, and provides general intuition about fiscal externalities, as well as explaining my numerical results. If UI benefits increase total earnings, this welfare-increasing fiscal externality will appear larger when I account for larger taxes, and the optimal benefit level will increase. If, on the other hand, the effect of UI on wages is zero, as has commonly been assumed, the only behavioural effect of benefits will be to increase unemployment, reducing total earnings, and the fiscal externality will be negative. As demonstrated in the numerical results, the reduction in the optimal benefit level in this case can be substantial.

Next, I present results on the role of E_b^y, to demonstrate that the value of this parameter could be important;[9] these results are straightforward, and begin with the following proposition.

Proposition 3. *For $E_b^{y2} > E_b^{y1}$, $\frac{dW}{db}(b; P, E_b^{y2}) > \frac{dW}{db}(b; P, E_b^{y1})$.*

[8]This is not, however, a restrictive assumption relying on quasi-concavity. If everything is continuous, then a marginal increase in the estimated value of P will lead to a marginal change in the optimal b according to the sign of $\frac{d(sy_n)}{db}$. Supposing that $\frac{d(sy_n)}{db} > 0$, b^* will only increase with P as long as it stays in a range where $\frac{d(sy_n)}{db} > 0$, so it can never increase out of this range, and thus a change in the estimated P can never move the estimated optimal b enough to change the sign of $\frac{d(sy_n)}{db}$. If there is a value of b for which $\frac{d(sy_n)}{db}$ takes the opposite sign, there must be no value of P such that this b would be optimal.

[9]The notation is now slightly altered to allow E_b^y to enter $\frac{dW}{db}$ and b^* as an argument.

Proof. Combining (H.2) and (15), I immediately get:

$$\frac{dW}{db}(b;P,E_b^{y2}) - \frac{dW}{db}(b;P,E_b^{y1})$$
$$= \frac{2u}{(1-u)\psi}\left[\frac{\Delta c}{c_1}R-(1-u)\right]\left[\frac{-\delta s}{2(1-u)}\right]\left[E_b^{y2}-E_b^{y1}\right]. \qquad \text{(M.1)}$$

Given that $E_b^{y2} > E_b^{y1}$, and that the middle two terms are both negative, this expression is always positive. □

A higher value of E_b^y means that b has a more positive effect on wages, meaning a smaller tax increase to pay for benefits, and thus a larger welfare gain from higher UI. The two following simple corollaries follow the pattern of the previous two.

Corollary 3. *For the current value of* b*, if* $\frac{dW}{db}(b;P,E_b^{y1}) = 0$ *or* $\frac{dW}{db}(b;P,E_b^{y2}) = 0$*, or if* $\frac{dW}{db}(b;P,E_b^{y1}) < 0$ *and* $\frac{dW}{db}(b;P,E_b^{y2}) > 0$*,* $b^*(P,E_b^{y2}) > b^*(P,E_b^{y1})$*.*

Corollary 4. *For statistical extrapolations of* $\chi_1 = \{\frac{\Delta c}{c_1}, R, s, E_b^D\}$ *that do not depend on the estimated value of* E_b^y*, i.e.* $\chi_1(b;E_b^y) = \chi_1(b)$*,* $b^*(P,E_b^{y2}) > b^*(P,E_b^{y1})$*.*

If the current b is the estimated optimal value for one of the values of E_b^y under consideration, or if the signs of $\frac{dW}{db}$ are opposite, then I can make an unambiguous statement. More generally, once I define a statistical extrapolation that does not depend on E_b^y, I can state that a researcher choosing a larger value of E_b^y will always find a larger optimal b.

I have now shown that higher E_b^y increases the optimal value of b, and found the conditions under which a higher value of P increases or decreases the optimal b; the final analytical results concern the interaction of P and E_b^y. As already mentioned, Baily (1978) is among the few papers that acknowledge the fact that a parameter like E_b^y could enter into optimal UI calculations, but he ultimately drops this parameter from his equation on the grounds that, since the UI payroll tax is quite small, it will have little effect on the results. However, E_b^y is more important when P is large, both to social welfare and to the calculation of the optimal value of b; a demonstration of this begins with the following proposition.

Proposition 4. *For* $E_b^{y2} > E_b^{y1}$, $\frac{dW}{db}(b; P, E_b^{y2}) - \frac{dW}{db}(b; P, E_b^{y1}) > \frac{dW}{db}(b; 0, E_b^{y2}) - \frac{dW}{db}(b; 0, E_b^{y1})$.

Proof. I start with (M.1), and from the definition of ψ:

$$\left[\frac{dW}{db}(b; P, E_b^{y2}) - \frac{dW}{db}(b; P, E_b^{y1})\right] - \left[\frac{dW}{db}(b; 0, E_b^{y2}) - \frac{dW}{db}(b; 0, E_b^{y1})\right]$$

$$= \frac{-\delta s}{(1-u)^2 b}\left[\frac{\Delta c}{c_1}R - (1-u)\right]\left[E_b^{y2} - E_b^{y1}\right] P.$$

The first two terms are negative, and the latter two are positive, so this equation is positive. □

This proposition says that the effect of E_b^y on the welfare derivative is increasing in P. Thus, it may be true that a researcher who ignores P will find that the value of E_b^y is relatively unimportant to their calculations, but when P is large, the tax rate will also be large, and E_b^y will matter far more to the value of the welfare derivative. Proposition 4 can also be interpreted as saying that the importance of P to the welfare derivative is increasing in E_b^y.

The final analytical result addresses the question of whether E_b^y is more important in determining the value of the optimal b when P is large. The results so far make it logical to suspect that $b^*(P; E_b^y) - b^*(0; E_b^y)$ is increasing in E_b^y, i.e. that the increase in b^* caused by P is more positive when E_b^y is larger; after all, I have proved that b^* is increasing in E_b^y, and that the difference in the welfare derivative for different values of E_b^y is increasing in

P. This suspicion, however, cannot be turned into proof without unusual and unintuitive assumptions; I can, however, prove a somewhat weaker result, as summarized below.

Proposition 5. *For continuous statistical extrapolations that do not depend on the estimated values of P and E_b^y, if $\frac{dE_b^D}{db} \geq 0$, $\frac{dR}{db} = 0$, $E_b^D > -1$, and $\frac{d}{db}\left(\frac{\frac{\Delta c}{c_1}}{1-u}\right) < 0$, the following is true:*

- *if $\exists$ an E_b^{y*} such that $b^*(P, E_b^{y*}) = b^*(0, E_b^{y*})$, then $b^*(P, E_b^{y2}) > b^*(0, E_b^{y2})$ for $E_b^{y2} > E_b^{y*}$ and $b^*(P, E_b^{y1}) < b^*(0, E_b^{y1})$ for $E_b^{y1} < E_b^{y*}$.*

Proof. I begin with the fact that, at the optimum, $\frac{\Delta c}{c_1} R E_b^\tau = (1-u)\left(E_b^\tau - \psi\right)$; using (15) and rearranging, this becomes:

$$\frac{\Delta c}{c_1} R\psi(1+E_b^D) - (1-u)\psi E_b^D = \frac{\delta}{2(1-u)}\left[sE_b^y - (1-s)E_b^D\right]\left[\frac{\Delta c}{c_1}R - (1-u)\right].$$

Observe that, because $\frac{\Delta c}{c_1}R < 1-u$, $sE_b^y - (1-s)E_b^D > 0$ at the optimum if and only if $\frac{\Delta c}{c_1}R(1+E_b^D) - (1-u)E_b^D < 0$. I wish to show that $b^*(P, E_b^{y2}) > b^*(0, E_b^{y2})$ and $b^*(P, E_b^{y1}) < b^*(0, E_b^{y1})$ for $E_b^{y2} > E_b^{y*} > E_b^{y1}$, so Corollary 2 says that $sE_b^y - (1-s)E_b^D$ must be positive for E_b^{y2} and negative for E_b^{y1}. Then, if I define $X(b) = \frac{\Delta c}{c_1}R(1+E_b^D) - (1-u)E_b^D$, I want $X < 0$ at the optimum for E_b^{y2} and $X > 0$ for E_b^{y1}; given that I am considering continuous statistical extrapolations, a sufficient and necessary condition is that $\frac{dX}{db} < 0$ at $X = 0$. The derivative is:

$$\frac{dX}{db} = R(1+E_b^D)\frac{d\left(\frac{\Delta c}{c_1}\right)}{db} + \frac{\Delta c}{c_1}(1+E_b^D)\frac{dR}{db} + \frac{\Delta c}{c_1}R\frac{dE_b^D}{db}$$
$$-E_b^D\frac{d(1-u)}{db} - (1-u)\frac{dE_b^D}{db}$$

and at $X = 0$, $\frac{\Delta c}{c_1}R(1+E_b^D) = (1-u)E_b^D$, and thus:

$$\frac{dX}{db}|_{X=0} = \frac{\Delta c}{c_1}(1+E_b^D)\frac{dR}{db} + \left[\frac{\Delta c}{c_1}R - (1-u)\right]\frac{dE_b^D}{db}$$

$$+\frac{R(1+E_b^D)}{(1-u)}\left[(1-u)\frac{d\left(\frac{\Delta c}{c_1}\right)}{db}-\frac{\Delta c}{c_1}\frac{d(1-u)}{db}\right].$$

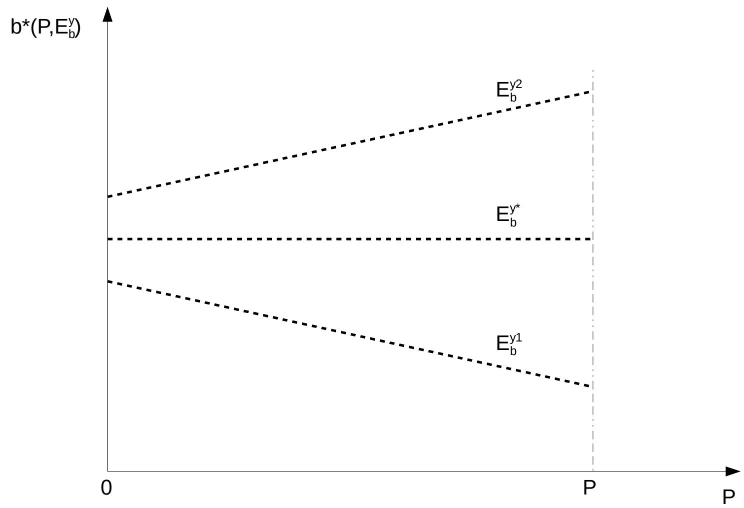
Sufficient conditions for this to be negative are that $\frac{dR}{db}=0$, $\frac{dE_b^D}{db}\geq 0$, $1+E_b^D>0$ and $(1-u)\frac{d\left(\frac{\Delta c}{c_1}\right)}{db}<\frac{\Delta c}{c_1}\frac{d(1-u)}{db}$. The first two assumptions are standard, and I make them in my numerical analysis; $\frac{dR}{db}$ is commonly assumed to equal zero, as it would with a CRRA utility function, and Chetty (2006) states that estimates of $\frac{dE_b^D}{db}$ "are broadly similar across studies with different levels of benefit generosity." The third assumption is a formality, as a nearly universal finding of the empirical literature is that E_b^D is positive. The final assumption requires a bit more explanation; it is easiest to understand when written as $\frac{d}{db}\left(\frac{\frac{\Delta c}{c_1}}{1-u}\right)<0$. The consumption gap $\frac{\Delta c}{c_1}$ is likely to be much smaller than $1-u$, and to decline faster, as the former is always less than one and could reach or even drop below zero, whereas $1-u$ is always at least as large as $1-\frac{\delta}{2}$. Therefore, this condition is likely to be satisfied in nearly every case of interest, and this assumption is supported by the numerical results in appendix B.2 of the main paper in all cases in which the optimal replacement rate is above zero; my functional form assumptions cause $\frac{d(1-u)}{db}$ to become unboundedly large and negative as benefits approach zero. □

This proposition says that, although I cannot prove the stronger condition that $b^*(P;E_b^y)-b^*(0;E_b^y)$ is increasing in E_b^y, I can state that for small values of E_b^y, $b^*(P,E_b^y)<b^*(0,E_b^y)$, and vice-versa for sufficiently large values of E_b^y;[10] this result is summarized by the diagram in Figure M.2. Therefore, at least locally around E_b^{y*}, the stronger condition will hold, and I show in

[10]In the unlikely case that an increase in E_b^y causes an increase in the optimal b which makes s decrease sufficiently quickly, the critical value E_b^{y*} may not exist; in that case, $b^*(P)-b^*(0)$ is always negative as long as $E_b^u>0$.

my numerical results that the stronger condition does describe the general behaviour of b^* for the parameters and functional forms that I use.

Figure M.2: Consequences of Proposition 5



The results derived in this appendix apply in particular to UI, but similar results will also apply in the context of other government programs with impacts on the labour market. The idea that the direction of the change in optimal policy caused by fiscal externalities depends only on the direction of the program's effect on total taxable income is intuitive and more general than the current context, as is the result that effects of a program on wages are more important when the full size of government is taken into account.

N Extensions to Baily Model

This appendix will analyze a variety of extensions to the Baily model, including stochastic duration of unemployment, within-period borrowing constraints, use of a second-order Taylor series expansion of marginal utility, and variable labour supply on the initial job. I will present results in each of these cases with both the baseline value of $R = 2$ and $R = 5$, and I will demonstrate that, although the formulas change somewhat in each case, as do the specific numerical results, the qualitative effects of fiscal externalities change very little. Finally, I show that, if G is endogenous, the impact of fiscal externalities is either unchanged or larger, depending on which elasticities we can actually observe empirically.

N.1 Stochastic Duration of Unemployment

I first consider the effect of allowing the duration of unemployment to be stochastic. I follow Baily's approach of defining the actual duration of unemployment $(1 - \tilde{s})$ as:

$$(1 - \tilde{s}) = [1 - s(e, y_n)] + v$$

where s is deterministic, and v is a stochastic term with mean zero which is uncorrelated with s.[11]

If I now denote second-period consumption if the worker loses their job as $\tilde{c_u}$, then:

$$\begin{aligned}\tilde{c_u} &= (1 - \tilde{s})(b - e) + \tilde{s} y_n (1 - \tau) + L + k \\ &= c_u - v\Delta y\end{aligned}$$

where c_u is defined as before, and $\Delta y = y_n(1 - \tau) - (b - e)$. Utility can now be written as:

$$V = U[y(1 - \tau) + L - k] + (1 - \delta)U[y(1 - \tau) + L + k] + \delta E_v[U(\tilde{c_u})].$$

(6) and (7) now have to be replaced by:

$$\frac{\partial V}{\partial b} = \delta E_v[U'(\tilde{c_u})(1 - s + v)]$$

[11] As noted by Baily, this can only be an approximation given that $(s - v)$ is constrained to lie in $(0, 1)$.

$$\frac{\partial V}{\partial \tau} = -yU'(c_1) - (1-\delta)yU'(c_e) - \delta y_n E_v[U'(\tilde{c_u})(s-v)].$$

A first-order Taylor series expansion of $U'(c_1)$ gives $U'(c_1) = U'(c_u) + \Delta c U''(\theta)$ as before, and I perform a similar expansion of $U'(\tilde{c_u})$:

$$\begin{aligned} U'(\tilde{c_u}) &= U'(c_u) + U''(\gamma)(\tilde{c_u} - c_u) \\ &= U'(c_u) - v\Delta y U''(\gamma) \end{aligned}$$

where γ is somewhere between c_u and $\tilde{c_u}$. Upon reaching this point in the calculations, Baily (1978) implicitly makes an assumption that he does not state explicitly, which is that $U''(\gamma)$ is uncorrelated with v and v^2, capturing an intuition that the average first and second derivatives shouldn't be too far from the respective derivatives at the average c_u, as well as greatly simplifying the algebra. I make the same assumption, and therefore:

$$E_v[U'(\tilde{c_u})] = U'(c_u)$$

$$E_v[U'(\tilde{c_u})v] = -\Delta y E_v[U''(\gamma)]Var(v).$$

As a result, the individual's first-order condition for savings can now be written as:

$$\frac{\partial V}{\partial k} = -U'(c_1) + (1-\delta)U'(c_e) + \delta U'(c_u) = 0.$$

As before, I make the assumptions that $y_n = y$ and $c_1 U''(\theta) = c_u U''(c_u)$, and to this I add the assumption that $E[U''(\gamma)] = U''(\theta)$, which will tend towards underestimating the welfare gain from raising b. I then combine the results above and write the welfare derivative as:

$$\frac{dW}{db} = 2y\frac{\Delta c}{c_1}R\frac{d\tau}{db} + \delta\frac{\Delta y}{c_1}RVar(v) + \delta y\frac{\Delta y}{c_1}RVar(v)\frac{d\tau}{db} - 2(1-u)y\left[\frac{d\tau}{db} - \omega\right]$$

which can also be written as:

$$\frac{dW}{db} = \frac{2u}{(1-u)\psi}\left[\frac{\Delta c}{c_1}R + \frac{\Delta y}{c_1}\frac{RVar(v)}{1-s}\right]E_b^\tau - \frac{2u}{\psi}\left[1 + \frac{\Delta y}{c_1}\frac{RVar(v)}{1-s}\right]\left[E_b^\tau - \psi\right].$$

The budget constraint takes an expectation over all workers, and so is unchanged, and the equation for the optimum is:

$$\frac{\Delta c}{c_1}R + \frac{\Delta y}{c_1}\frac{RVar(v)}{1-s} = (1-u)\left[1 + \frac{\Delta y}{c_1}\frac{RVar(v)}{1-s}\right]\frac{E_b^\tau - \psi}{E_b^\tau}. \quad \text{(N.1)}$$

If I make the same assumptions as Baily, then this formula collapses to that used in his extension to stochastic unemployment durations. Most of the terms in (N.1) have exactly the same interpretation as before, or, as in the case of u and s, still work as averages or expectations, but there are two new terms to consider: $\frac{\Delta y}{c_1}$ and $Var(v)$. The latter is also the variance of the duration of unemployment $(1-s)$, and to evaluate this parameter, I turn to Chetty (2008), who estimates a mean duration of unemployment of 18.3 weeks, and a standard deviation of 14.2, so I normalize the standard deviation by the mean and write $std(v) = \frac{14.2}{18.3}(1-s_0)$, and therefore $Var(v) = \left(\frac{14.2}{18.3}\right)^2(1-s_0)^2$.[12] Meanwhile, in the absence of any better evidence, I will use Baily's assumption that $\frac{\Delta y}{c_1} = 1-r$. Evaluation of (N.1) then gives the results displayed in Tables N.1 and N.2.

As can be seen, allowing for an uncertain duration of unemployment tends to make the optimal rate closer to one, since the desire to provide full insurance is made greater by the uncertainty; this means a decrease in cases where the optimal rate was above one, as it is no longer as desirable to "over-insure" when unemployed individuals face uncertainty about duration. The qualitative conclusion remains the same, however, regarding the effect of the fiscal externality from income taxes: the optimal replacement rate decreases for lower values of s and especially E_b^y, whereas it increases for higher values.

[12]There are potential offsetting biases in these calculations; Chetty (2008) uses a sample in which the duration of unemployment is truncated at 50 weeks, suggesting I may be underestimating $Var(v)$, but on the other hand, Chetty's is an unconditional variance, some of which may be explained by individual characteristics, which means $Var(v)$ may be an overestimate.

Table N.1: Optimal Replacement Rates Calculated from (N.1) for $R = 2$

Optimal r for Benchmark Scenario:					
		s_0			
		0.648	0.725	0.8	0.863
	-0.0816	0.6529	0.6208	0.5812	0.5367
	0	0.6590	0.6303	0.5969	0.5630
E_b^y	0.048	0.6626	0.6360	0.6063	0.5790
	0.096	0.6662	0.6417	0.6157	0.5954
	0.192	0.6735	0.6532	0.6351	0.6292
	0.3072	0.6824	0.6673	0.6590	0.6720
Optimal r for Fiscal Externality Scenario:					
		s_0			
		0.648	0.725	0.8	0.863
	-0.0816	0	0	0	0
	0	0	0	0	0
E_b^y	0.048	0.5259	0.5179	0.5371	0.6035
	0.096	0.5946	0.6199	0.6864	0.8138
	0.192	0.7036	0.7738	0.9044	1.1195
	0.3072	0.8095	0.9196	1.1081	1.4008

Table N.2: Optimal Replacement Rates Calculated from (N.1) for $R = 5$

Optimal r for Benchmark Scenario:					
		s_0			
		0.648	0.725	0.8	0.863
	-0.0816	0.7961	0.7779	0.7560	0.7322
	0	0.7986	0.7819	0.7626	0.7432
E_b^y	0.048	0.8002	0.7843	0.7665	0.7499
	0.096	0.8017	0.7867	0.7705	0.7567
	0.192	0.8048	0.7916	0.7786	0.7708
	0.3072	0.8085	0.7975	0.7887	0.7887
Optimal r for Fiscal Externality Scenario:					
		s_0			
		0.648	0.725	0.8	0.863
	-0.0816	0.7024	0.6615	0.6017	0.5174
	0	0.7349	0.7131	0.6877	0.6624
E_b^y	0.048	0.7541	0.7436	0.7394	0.7522
	0.096	0.7733	0.7743	0.7914	0.8421
	0.192	0.8115	0.8353	0.8943	1.0170
	0.3072	0.8569	0.9075	1.0136	1.2108

Indeed, the pairwise comparisons between the side-by-side tables are identical in the sense that, if the optimal replacement rate is higher in the fiscal externality scenario in Table 14 or K.2, the same is true in Table N.1 or N.2, and vice-versa.

N.2 Within-Period Borrowing Constraints

Another unrealistic feature of the basic two-period model is the assumption that individuals can not only save or borrow as much as they want across periods, but that they can also perfectly smooth consumption within the second period. Recent work, in particular that of Chetty (2008), has emphasized the importance of liquidity constraints among the unemployed and the beneficial role of UI in loosening these constraints. I will therefore consider the case of no borrowing during unemployment; I assume that utility is additively time-separable within the second period, so that second period utility of a worker who loses their job is $(1-s)U(c_u)+sU(c_n)$, where c_u is now per-period consumption while unemployed and c_n is per-period consumption when re-employed in a new job.[13] I also assume that, if a worker loses their job, any savings from the first period are completely consumed while unemployed; none of those savings are kept for consumption when re-employed.[14] I can therefore write total utility as:

$$V = U[y(1-\tau)+L-k] + (1-\delta)U[y(1-\tau)+L+k]$$

[13]Chetty (2006) argues that, in his model, the nature of borrowing constraints does not change the optimal UI formula, as this effect will simply show up in the magnitude of the consumption drop. In a sense, this is correct in my analysis as well, but how I interpret borrowing constraints changes what I call the value of consumption during unemployment; I previously defined c_u as the total consumption in the second period if a worker experiences a spell of unemployment, whereas I now define c_u to be consumption while unemployed.

[14]Given that unemployment durations are deterministic, as long as y_n is not too far from y, there is no reason for a worker to save more than they would want to consume in a spell of unemployment.

$$+\delta\left[(1-s)U\left((b-e)+L+\frac{k}{1-s}\right)+sU\left(y_n(1-\tau)+L\right)\right].$$

(6) still holds, and (7) is now replaced by:

$$\frac{\partial V}{\partial \tau}=-yU'(c_1)-(1-\delta)yU'(c_e)-\delta s y_n U'(c_n).$$

I replace $U'(c_e)$ using the first-order condition for saving, as before, and I assume that $c_n = c_1$, which is generally consistent with the finding in Gruber (1997) that workers who lose their job in one year but are re-employed in the following year see their consumption return to within 4% of their pre-unemployment consumption. Combining this with the usual Taylor series expansion of $U'(c_1)$:

$$\frac{\partial V}{\partial \tau}=-[(2-\delta)y+\delta s y_n]U'(c_u)-[2y+\delta s y_n]\Delta c U''(\theta).$$

Putting this together with (6):

$$\frac{dW}{db}=[2+\delta s]y\frac{\Delta c}{c_1}R\frac{d\tau}{db}-2(1-u)y\left(\frac{d\tau}{db}-\omega\right)$$

and therefore the equation for the optimum is:

$$\frac{\Delta c}{c_1}R=\frac{2(1-u)}{2+\delta s}\frac{E_b^{\tau}-\psi}{E_b^{\tau}}. \tag{N.2}$$

E_b^{τ} is the same as before, so this equation is almost identical to (11), and it is easy to introduce the extra δs term into the calculations. Solving for the optimal replacement rate generates the results found in Tables N.3 and N.4.

The pattern of the results changes a little, as the optimal replacement rates generally tend to move closer to $\frac{0.222}{0.265}$. In a few cases with $R = 5$ and high E_b^y and s_0, anomalous results occur in which the local maximum obtained at a replacement rate near one is not estimated to be the global maximum, which appears to occur at zero. In these cases, the assumption that unemployment

Table N.3: Optimal Replacement Rates Calculated from (N.2) for $R = 2$

Optimal r for Benchmark Scenario:

		s_0			
		0.648	0.725	0.8	0.863
E_b^y	-0.0816	0.4850	0.4947	0.5098	0.5316
	0	0.4934	0.5063	0.5263	0.5551
	0.048	0.4985	0.5133	0.5362	0.5694
	0.096	0.5035	0.5203	0.5463	0.5841
	0.192	0.5137	0.5344	0.5670	0.6146
	0.3072	0.5260	0.5518	0.5926	0.6534

Optimal r for Fiscal Externality Scenario:

		s_0			
		0.648	0.725	0.8	0.863
E_b^y	-0.0816	0	0	0	0
	0	0	0	0	0
	0.048	0.0357	0.3371	0.4628	0.5931
	0.096	0.4040	0.5082	0.6368	0.7937
	0.192	0.5895	0.7127	0.8796	1.0970
	0.3072	0.7412	0.8931	1.1044	1.3833

Table N.4: Optimal Replacement Rates Calculated from (N.2) for $R = 5$

Optimal r for Benchmark Scenario:

		s_0			
		0.648	0.725	0.8	0.863
E_b^y	-0.0816	0.6963	0.7002	0.7063	0.7151
	0	0.6995	0.7047	0.7128	0.7244
	0.048	0.7014	0.7074	0.7167	0.7301
	0.096	0.7034	0.7102	0.7207	0.7359
	0.192	0.7073	0.7157	0.7289	0.7481
	0.3072	0.7120	0.7225	0.7390	0.7636

Optimal r for Fiscal Externality Scenario:

		s_0			
		0.648	0.725	0.8	0.863
E_b^y	-0.0816	0.5673	0.5616	0.5557	0.5536
	0	0.6125	0.6220	0.6366	0.6571
	0.048	0.6396	0.6594	0.6896	0.7327
	0.096	0.6670	0.6976	0.7452	*0/0.8157
	0.192	0.7220	0.7753	*0/0.8604	*0/0.9909
	0.3072	0.7876	0.8685	*0/0.9982	*0/1.1963

*Global Maximum/Local Maximum

goes to zero as benefits go to zero is partly responsible, as is a failure of an assumption that $\frac{\Delta c}{c_1} R < \frac{2(1-u)}{2+\delta s}$.[15] However, aside from these cases, the changes tend to be quite small, surprisingly so given the shift in the nature of borrowing constraints, as zeros still occur for $R = 2$ and low values of E_b^y, and the qualitative comparisons are similar to those from the basic model. One explanation for this is that I still allow for unrestricted savings in the first period, so workers take into account the borrowing constraints in the second period when they make their savings decision, and the desire for within-period consumption smoothing may be fairly small. Additionally, using the same expression for $\frac{\Delta c}{c_1}$ when I have redefined c_u to be consumption while unemployed will tend to shift the results downwards, offsetting the tendency of optimal benefit levels to increase.

N.3 Second-Order Taylor Series Expansion of Marginal Utility

Chetty (2006) argues that ignoring third and higher derivatives of the utility function may be a mistake; he reports that, for simulation exercises using a CRRA utility function, using a first-order expansion of marginal utility can sometimes lead to an underestimate of the true optimal replacement rate on the order of 30%, whereas a revised welfare equation using a second-order expansion reduces this error to less than 4%. The model used by Chetty (2006) is somewhat different from mine, and he writes all marginal utilities in terms of consumption while employed rather than $U'(c_u)$, so the results are not directly comparable.[16] However, I will now explore how the results change

[15] $\frac{\Delta c}{c_1} R > \frac{2(1-u)}{2+\delta s}$ implies $\frac{\partial V}{\partial \tau} > 0$, while I also estimate that $\frac{d\tau}{db} < 0$.

[16] The first-order Taylor series used in my paper is in fact an equality, not an approximation; it is the assumption that $c_1 U''(\theta) = c_u U''(c_u)$ which generates the potential for error. As already discussed, that assumption tends to be a liberal one, but Chetty's effective

when I use a second-order Taylor series expansion of marginal utility.

To do so, I must follow the approach of Chetty (2006) and rewrite my expression in terms of $U'(c_1)$ rather than $U'(c_u)$, although this will hinder the comparability of my results with those of the baseline case. I begin with (6) and (7), and the standard first-order condition for saving. Next, I use a new Taylor series expansion of $U'(c_u)$ around $U'(c_1)$:

$$U'(c_u) = U'(c_1) - \Delta c U''(c_1) + \Delta c^2 \frac{U'''(\theta)}{2}$$

where θ is not necessarily the same value as before, but is still between c_1 and c_u. Using this to replace $U'(c_u)$ in both (6) and (7):

$$\frac{dV}{db} = 2u\left[U'(c_1) - \Delta c U''(c_1) + \Delta c^2 \frac{U'''(\theta)}{2}\right]$$

$$-\left[[(2-\delta)y + \delta s y_n]U'(c_1) + \delta(y - s y_n)\left(\Delta c U''(c_1) - \Delta c^2 \frac{U'''(\theta)}{2}\right)\right]\frac{d\tau}{db}.$$

I make the usual assumption that $y_n = y$, and add the modified assumption that $\theta = c_1$, and then a bit of rearranging gives:

$$\frac{dW_1}{db} \equiv \frac{\frac{dV}{db}}{U'(c_1)} = 2y\left(\frac{\Delta c}{c_1}R + \frac{1}{2}\left(\frac{\Delta c}{c_1}\right)^2 R\pi\right)\frac{d\tau}{db}$$

$$-2(1-u)y\left(1 + \frac{\Delta c}{c_1}R + \frac{1}{2}\left(\frac{\Delta c}{c_1}\right)^2 R\pi\right)\left[\frac{d\tau}{db} - \omega\right]$$

where $\pi = \frac{-c_1 U'''(c_1)}{U''(c_1)}$ is the coefficient of relative prudence. Therefore, the equation for the optimum is:

$$\frac{\Delta c}{c_1}R + \frac{1}{2}\left(\frac{\Delta c}{c_1}\right)^2 R\pi = (1-u)\left(1 + \frac{\Delta c}{c_1}R + \frac{1}{2}\left(\frac{\Delta c}{c_1}\right)^2 R\pi\right)\frac{E_b^\tau - \psi}{E_b^\tau} \quad \text{(N.3)}$$

assumption that $U''(\theta)$ is equal to U'' at the average level of consumption while employed is a conservative one in his context, which explains why this leads to an underestimate in his paper. Baily's assumption that the E_b^τ in the denominator of the right-hand side of (11) is equal to one is, in the context of his model, a significant reason for underestimation of the optimal b.

where E_b^τ is unchanged and thus still given by (15).

I can use parameter values and functions as before, but there is one additional parameter to select: the coefficient of relative prudence. In a CRRA utility function $U(c) = \frac{c^{1-R}}{1-R}$, $\pi = \frac{-cU'''(c)}{U''(c)} = R + 1$, so one possibility is to set $\pi = R + 1$. However, previous studies have tended to find low estimates of relative prudence; Merrigan and Normandin (1996) are towards the high end of the results in the literature when they find estimates ranging from 1.78 to 2.33. I will therefore use a value of $\pi = 2$, and the results from evaluation of the optimal replacement rate are displayed in Tables N.5 and N.6.

The results this time are somewhat different quantitatively, in that optimal replacement rates are zero for low values of E_b^y even for $R = 5$. However, the qualitative comparison remains the same, right down to nearly the exact same pairwise comparisons: at low values of s and especially E_b^y, the fiscal externality term considerably reduces the optimal replacement rate, whereas at higher values it considerably increases it.

N.4 Variable Labour Supply

To this point, I have assumed that y is fixed, and thus ignored any distortionary effects of taxes on labour supply among the employed. Chetty (2006) points out that, with a lump-sum tax on workers, the envelope condition means that whether or not individuals can change the amount of their labour supply while employed is irrelevant to the optimal UI calculation. However, with a proportional tax, changes in y have an effect through the government budget constraint. Saez (2002) argues that much of the responsiveness of modest-income workers is on the extensive margin, which is already largely captured here by the decision about whether or not to seek work, but all the same I will examine how significant this effect could be. I begin by rewriting the

Table N.5: Optimal Replacement Rates Calculated from (N.3) for $R = 2$

Optimal r for Benchmark Scenario:					
		s_0			
		0.648	0.725	0.8	0.863
	-0.0816	0.4000	0.3947	0.3858	0.3707
	0	0.4124	0.4124	0.4124	0.4124
E_b^y	0.048	0.4196	0.4227	0.4281	0.4371
	0.096	0.4269	0.4331	0.4438	0.4620
	0.192	0.4414	0.4539	0.4755	0.5124
	0.3072	0.4588	0.4788	0.5138	0.5741
Optimal r for Fiscal Externality Scenario:					
		s_0			
		0.648	0.725	0.8	0.863
	-0.0816	0	0	0	0
	0	0	0	0	0
E_b^y	0.048	0.0232	0.0846	0.3205	0.5077
	0.096	0.2943	0.4390	0.5975	0.7846
	0.192	0.5601	0.6993	0.8839	1.1255
	0.3072	0.7345	0.8964	1.1194	1.4180

Table N.6: Optimal Replacement Rates Calculated from (N.3) for $R = 5$

Optimal r for Benchmark Scenario:					
		s_0			
		0.648	0.725	0.8	0.863
	-0.0816	0.6522	0.6499	0.6459	0.6392
	0	0.6574	0.6574	0.6574	0.6574
E_b^y	0.048	0.6604	0.6618	0.6641	0.6682
	0.096	0.6634	0.6662	0.6709	0.6790
	0.192	0.6695	0.6750	0.6846	0.7008
	0.3072	0.6768	0.6857	0.7011	0.7274
Optimal r for Fiscal Externality Scenario:					
		s_0			
		0.648	0.725	0.8	0.863
	-0.0816	0	0	0	0
	0	0	0	0	0
E_b^y	0.048	0.5391	0.5691	0.6137	0.6770
	0.096	0.6017	0.6477	0.7151	0.8092
	0.192	0.6951	0.7638	0.8632	1.0005
	0.3072	0.7813	0.8705	0.9983	1.1721

utility function to allow for choice of y, assuming that the worker must make the same choice of y in both the first and second periods if they retain their job. If disutility from work effort, which I denote as $h(y)$, is separable from consumption, (3) becomes:

$$V = U[y(1-\tau) + L - k] + (1-\delta)U[y(1-\tau) + L + k] - (2-\delta)h(y)$$

$$+\delta U[(1-s)(b-e) + sy_n(1-\tau) + L + k] - \delta h(sy_n).$$

Because (6) and (7) are unchanged, both (10) and (11) remain valid; the only change is to the derivative of the government budget constraint. The latter now becomes:

$$\frac{d\tau}{db} = \frac{\delta(1-s) - \delta b\frac{ds}{db} - \delta\tau y_n\frac{ds}{db} - \delta s\tau\frac{dy_n}{db} - (2-\delta)\tau\frac{dy}{db}}{(2-\delta)y + \delta sy_n}.$$

and rewritten in terms of elasticities, this is equivalent to:

$$E_b^\tau = \psi + \psi E_b^u + \frac{u}{1-u}E_b^D - \frac{\delta s}{2(1-u)}E_b^y - \frac{2-\delta}{2(1-u)}\varepsilon_b^y \qquad \text{(N.4)}$$

where $\varepsilon_b^y = \frac{b}{y}\frac{dy}{db}$.

I now have to decide on a value for ε_b^y. When b increases, τ increases as well – unless E_b^y is so large as to actually lead to increased tax revenues, which cannot be the case at the optimum – so some version of an elasticity of taxable income is required. Gruber and Saez (2002) find an elasticity of taxable income with respect to the net-of-tax rate of 0.4;[17] using this, and assuming that the only effect of changes in b and τ on y go through the channel of taxes:

$$\varepsilon_b^y = \frac{dy}{db}\frac{b}{y} = \frac{dy}{d\tau}\frac{d\tau}{db}\frac{b}{y} = -0.4\frac{b}{1-\tau}\frac{d\tau}{db}.$$

[17] Their estimated elasticities are smaller for low and moderate income individuals, who are more likely to end up on UI, so this is likely to overestimate the distortionary effects of taxation.

To simplify the calculations, I replace $\frac{d\tau}{db}$ with the partial derivative:

$$\varepsilon_b^y \simeq -0.4\frac{b}{1-\tau}\left[\frac{\delta(1-s)}{((2-\delta)y+\delta s y_n}\right] \simeq -0.4\frac{\tau}{1-\tau}\psi.$$

Finally, I use the baseline tax rate of $\tau = 0.282$, so my estimate of the elasticity is $\varepsilon_b^y = \frac{-0.1128}{0.718}\psi$; I do not need to multiply this by 0.48, as this estimate is meant to apply to the entire universe of workers. The ensuing numerical results are displayed in Tables N.7 and N.8.

The inclusion of the labour supply elasticity tends to lower the optimal replacement rate, though in many cases not by much; in the $R = 5$ case, the effect is often almost negligible, whereas in the $R = 2$ case the effect can be somewhat larger for moderate values of E_b^y. However, the essential point remains that consideration of fiscal externalities can greatly change the results, either in a positive or negative direction; the pairwise comparisons are again nearly identical to the baseline.

N.5 Endogenous G

If G is not exogenous, but is instead chosen optimally by the government conditional on the value of b, then increases in UI benefits can be met either with tax increases or reductions in G. In appendix A.3 in the main paper, I show that the results from the structural model with endogenous G are almost identical to those from the baseline analysis. In this appendix, I consider the effect on the welfare analysis of the Baily model.

First, I assume some increasing function $g(G)$ for utility from G, so overall expected utility is:

$$V = U(c_1) + (1-\delta)U(c_e) + \delta U(c_u) + g(G).$$

Then, because the government chooses G optimally, it must be true that $\frac{dV}{dG} =$

Table N.7: Optimal Replacement Rates from (11) and (N.4) for $R = 2$

Optimal r for Benchmark Scenario:					
		s_0			
		0.648	0.725	0.8	0.863
E_b^y	-0.0816	0.3103	0.3133	0.3187	0.3278
	0	0.3184	0.3249	0.3362	0.3557
	0.048	0.3232	0.3317	0.3466	0.3725
	0.096	0.3280	0.3386	0.3572	0.3898
	0.192	0.3377	0.3526	0.3788	0.4254
	0.3072	0.3494	0.3695	0.4054	0.4704
Optimal r for Fiscal Externality Scenario:					
		s_0			
		0.648	0.725	0.8	0.863
E_b^y	-0.0816	0	0	0	0
	0	0	0	0	0
	0.048	0.0251	0.1070	0.2845	0.4462
	0.096	0.2560	0.3691	0.5103	0.6960
	0.192	0.4689	0.5954	0.7758	1.0308
	0.3072	0.6258	0.7808	1.0075	1.3299

Table N.8: Optimal Replacement Rates from (11) and (N.4) for $R = 5$

Optimal r for Benchmark Scenario:					
		s_0			
		0.648	0.725	0.8	0.863
E_b^y	-0.0816	0.6277	0.6289	0.6310	0.6346
	0	0.6306	0.6332	0.6376	0.6454
	0.048	0.6323	0.6357	0.6416	0.6519
	0.096	0.6341	0.6383	0.6457	0.6586
	0.192	0.6376	0.6435	0.6539	0.6725
	0.3072	0.6419	0.6499	0.6642	0.6902
Optimal r for Fiscal Externality Scenario:					
		s_0			
		0.648	0.725	0.8	0.863
E_b^y	-0.0816	0.4947	0.4754	0.4430	0.3911
	0	0.5432	0.5453	0.5488	0.5549
	0.048	0.5718	0.5868	0.6130	0.6584
	0.096	0.6002	0.6282	0.6770	0.7613
	0.192	0.6564	0.7099	0.8023	0.9579
	0.3072	0.7221	0.8046	0.9444	1.1711

$g'(G) + \frac{\partial V}{\partial \tau}\frac{d\tau}{dG}|_{db=0} = 0$. Meanwhile, the welfare derivative with respect to b is:

$$\begin{aligned} \frac{dV}{db} &= \frac{\partial V}{\partial b} + g'(G)\frac{dG}{db} + \frac{\partial V}{\partial \tau}\frac{d\tau}{db} \\ &= \frac{\partial V}{\partial b} + \frac{\partial V}{\partial \tau}\left[\frac{d\tau}{db} - \frac{d\tau}{dG}|_{db=0}\frac{dG}{db}\right]. \end{aligned}$$

The term in square brackets is the increase in τ accounting for the adjustment in G, plus the additional increase in τ that would happen without the adjustment of G; in other words, the total increase in τ that would result if G was held constant. To see this, notice that I can write:

$$\frac{d\tau}{db} = \frac{d\tau}{db}|_{dG=0} + \frac{d\tau}{dG}|_{db=0}\frac{dG}{db}$$

and therefore:

$$\frac{d\tau}{db} - \frac{d\tau}{dG}|_{db=0}\frac{dG}{db} = \frac{d\tau}{db}|_{dG=0}.$$

Therefore, the welfare derivative is exactly the same as before, with $\frac{d\tau}{db}$ now representing the tax increase that would be required to pay for increased b if G was held fixed. The important question is whether this is the $\frac{d\tau}{db}$ that we observe empirically; the variation in UI generosity exploited in many empirical studies, including Chetty (2008), is across states over time, so it is possible G is adjusted along with b within a state, but it is also possible that variation in G is not strongly related to that in b if variation is due to business cycle fluctuations. If $\frac{d\tau}{db}|_{dG=0}$ is what we observe, then the optimality condition in (14) or (16) is exactly correct, whereas if we observe $\frac{d\tau}{db}$ but G is actually endogenous, then the impact of fiscal externalities is even larger than previously estimated because we must add in the welfare cost of reduced G. Meanwhile, ψ will decline even further than before as b declines, since spending on G will increase, meaning that the extrapolation will lead to even larger costs of UI. Since there are no known estimates of the effect of changing b on the value of G, I cannot present numerical results, but appendix A.3 in the paper confirms that, if anything, the significance of fiscal externalities is slightly stronger with endogenous G.

N.6 Summary of Extensions

In each of the first four extensions considered, altering the model generally does change the numerical results; allowing for a stochastic duration of unemployment or second-period borrowing constraints tends to move the optimal replacement rates closer to one, whereas allowing for variable y or using the third derivative of marginal utility tends to reduce the estimated optimal replacement rate. These results, however, are all remarkable similar in terms of what they tell us about the importance of fiscal externalities; the pairwise comparisons of optimal replacement rates in the benchmark and fiscal externality scenarios are nearly identical in each case. Finally, extending the model to account for endogenous G leaves the results for the welfare derivative and optimal UI unchanged or even more sensitive to fiscal externalities.

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