Labor Supply: Income and Substitution Effects

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Roadmap

1. Introduction
2. Some Empirical Facts
3. Before the Theory
4. Labor-Leisure Choice Model
5. Math Derivation of Slutsky Equation $*$
6. Some Applications
7. Math behind Applications $*$

Labor Supply Decisions

- People decide
  - **whether to work or not** *(extensive margin)*
  - **how many hours to work** *(intensive margin)*
  - how hard to work
  - when to quit a job
  - which skills to acquire
  - which occupations to enter
- What factors affect these decisions?
  - E.g. consider you are currently working on a part-time job and then (i) the wage becomes double or (ii) you win a lottery

Roadmap

Measures of labor supply

- **Extensive margin**: labor force participation rate
  - Labor force (LF) = employed (E) + unemployed (U)
  - LFP Rate = LF / working age population
- **Intensive margin**: working hour per worker

Labor Force Participation Rate (Male, Age 15+)

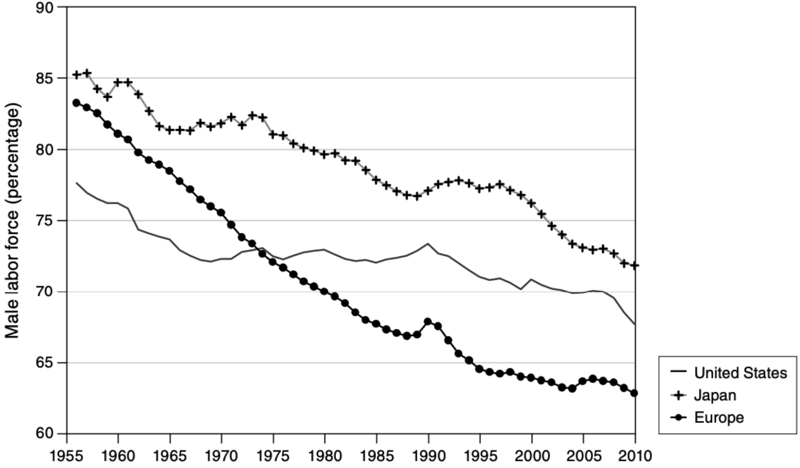


FIGURE 1.3
The evolution in civilian labor force participation rates of men in the United States, Europe, and Japan for persons 15 years of age and older, 1956–2010.

Source: OECD Annual Labor Force Statistics.

(What can cause the declines here?)

Labor Force Participation Rate (Male by Age)

Table 6.2

Labor Force Participation Rates for Males in the United States, by Age, 1900–2008 (percentage)

	Age Groups					
Year	14–19	16–19	20–24	25–44	45–64	Over 65
1900	61.1		91.7	96.3	93.3	68.3
1910	56.2		91.1	96.6	93.6	58.1
1920	52.6		90.9	97.1	93.8	60.1
1930	41.1		89.9	97.5	94.1	58.3
1940	34.4		88.0	95.0	88.7	41.5
1950	39.9	63.2	82.8	92.8	87.9	41.6
1960	38.1	56.1	86.1	95.2	89.0	30.6
1970	35.8	56.1	80.9	94.4	87.3	25.0
1980		60.5	85.9	95.4	82.2	19.0
1990		55.7	84.4	94.8	80.5	16.3
2000		52.8	82.6	93.0	80.4	17.7
2008		40.1	78.7	91.9	81.4	21.5

Sources: 1900–1950: Clarence D. Long, *The Labor Force under Changing Income and Employment* (Princeton, N.J.: Princeton University Press, 1958), Table A–2.

1960: U.S. Department of Commerce, Bureau of the Census, *Census of Population, 1960: Employment Status*, Subject Reports PC(2)–6A, Table 1.

1970: U.S. Department of Commerce, Bureau of the Census, *Census of Population, 1970: Employment Status and Work Experience*, Subject Reports PC(2)–6A, Table 1.

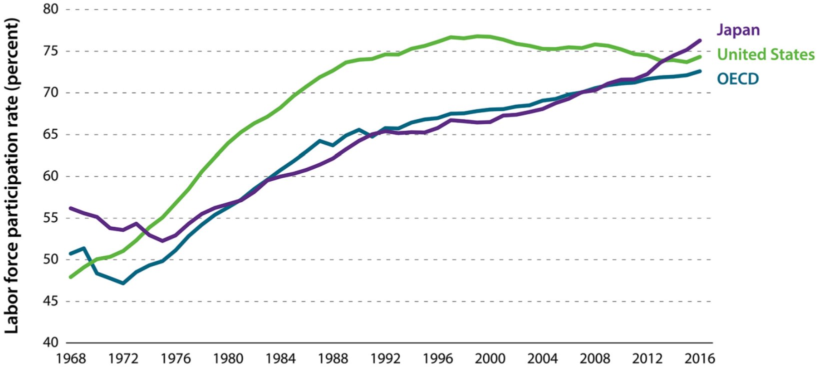
1980–2008: U.S. Census Bureau, *2010 Statistical Abstract*, Section 12 (Table 575), http://www.census.gov/compendia/statab/2010edition.html.

(Men are starting their work lives later and ending them earlier than before.)

Labor Force Participation Rate (Female, Prime-age)

FIGURE 1.

Labor Force Participation of Prime-age Women from 1968–2016, by Country



Source: OECD Labour Force Statistics.
Note: Prime-age indicates 25–54.

(Women had a very different trend compared to men! More next week!)

Working Hours per Worker: Trend (Boppart and Krusell, 2020)

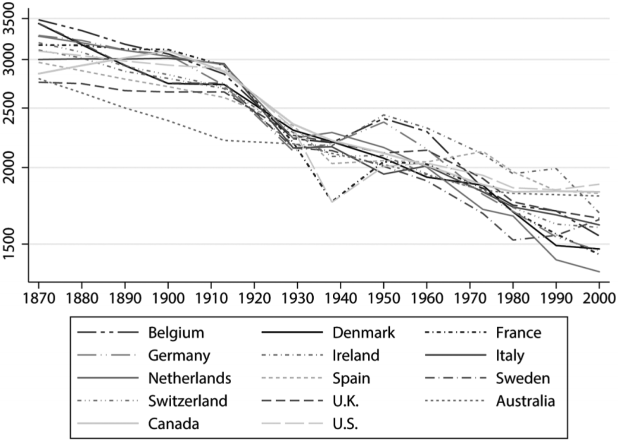


FIG. 1.—Hours worked per worker. The figure shows data for the following countries: Belgium, Denmark, France, Germany, Ireland, Italy, the Netherlands, Spain, Sweden, Switzerland, the United Kingdom, Australia, Canada, and the United States. The scale is logarithmic, which suggests that hours fall at roughly 0.57% per year. Source: Huberman and Minns (2007). Maddison (2001) shows a similar systematic decline in hours per capita. A color version of this figure is available online.

(What cause the declines here?)

Working Hours per Worker: Cross-country (Bick et al., 2018)

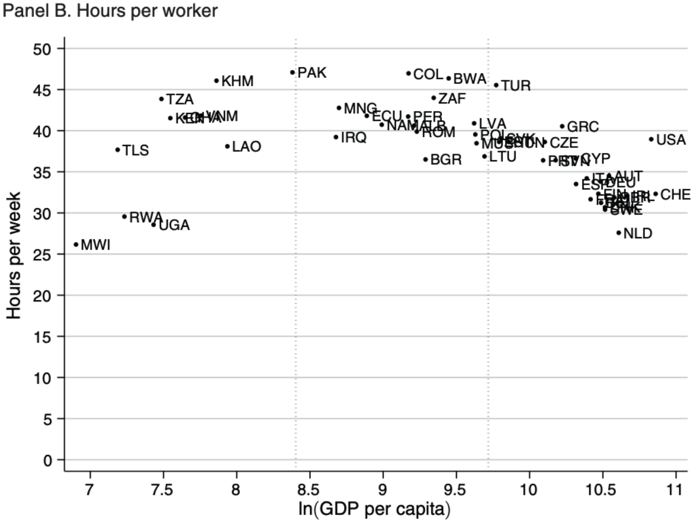


FIGURE 3. EXTENSIVE AND INTENSIVE MARGINS IN CORE COUNTRIES

(What cause the inverted-U shape here?)

Working Hours per Person: US vs OECD (Rogerson, 2024)

Table 1
Hours of Work per Person Relative to the United States

Considerably below the US level (<0.75)	Moderately below the US level (0.75, 0.85)	Slightly below the US level (0.85, 0.95)	At or above the US level (>0.95)
Italy (0.69)	Finland (0.77)	UK (0.85)	Canada (0.96)
France (0.70)	Austria (0.79)	Sweden (0.90)	Australia (0.98)
Belgium (0.72)	Norway (0.80)	Ireland (0.91)	United States (1.00)
Greece (0.73)	Netherlands (0.82)	Japan (0.91)	New Zealand (1.07)
Denmark (0.74)	Portugal (0.85)	Switzerland (0.93)	Korea (1.12)
Germany (0.74)			
Spain (0.75)			

Source: Author's calculation using data from OECD (2024a, c).
Note: Details of the calculation are in the online Appendix. Table shows average for 2015–2019.

(Why do Europeans and Japanese work less then Americans?)

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What are the Potential Drivers of Labor Supply?

- We focus on ”economics” factors b.c. in our economics models agents behave under ”economics” incentives
  - Wage; Income; Wealth
  - Leisure activities; Housework
  - Taxes; Welfare policies/programs
- General mechanisms are more useful and ”scientific” than just saying
  - ”Europeans are much lazier than Americans”
  - ”Japaneses have the culture of working hard”
- Furthermore,
  - culture is often formed due to economics incentives
  - it’s in fact not difficult to incorporate culture factors into econ models

Labor Supply in Roy Framework

- Consider a setting of either work or home production
- Two choices:
  - Work in labor market, receive wh^m
  - Work at home and produce ph^h
- A person i works in labor market if

$$wh_i^m > ph_i^h$$

- People who are relatively more productive in the market will work
- Total labor supply, which sums all individual choices, depends on
  - relative price w/p
  - joint distribution of human capital $F(h^m, h^h)$
- Here, only extensive margin of labor supply is considered

Setting of A Labor-Leisure Model

- Agent:
  - Individuals of working age
- Decision/Choices:
  - How many **hours for work/leisure** per day
  - Note this choice nests both extensive (0) and intensive margin
- Time:
  - Simple static choice
- Equlibrium:
  - Partial equilibrium where wage is taken as given

Can Workers Choose Working Hours?

- Don't employers set the hours of work? (e.g. Ford in 1926)

- Workers can
  - choose part-time vs full-time
  - select industries/occupations/firms with different working hours
  - shirk during their working time
  - initiate labor movements

- So the argument is that employer requirements on work hours will reflect workers' preferences, esp. in the long-run
  - What's behind cultural and political movements can be thus utility maximization

- But firms (labor demand side) surely have some power in setting working hours
  - Over business cycles (Kudoh et al., 2019)
  - Across industries/occupations (e.g. law or IB firms) (Bertrand et al., 2010))

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At a High Level

- The ”neoclassical theory of labor supply”: focus on individual choice
- An application of consumer theory: choose between two goods (consumption and leisure)
  - The tricky part: here agents simultaneously choose consumption and ”income” by choosing working hours
- Thus more close to what you have learned in your microeconomics class

Setting

- The agent has preference, i.e. a **utility function** $U(C, L)$
  - C is consumption of goods and services (w/ normalized price $p = 1$)
  - L is leisure
  - Assume $U(\cdot, \cdot)$ is a strictly increasing and strictly concave (intuition: decreasing marginal return)
- The agent has two endowments:
  - Disposable time T: 24 or 16 or 12 hours
  - Non-wage income Y: can be 0 or even negative (debt)
- The agent maximize utility by choosing L or working time H
  - $L + H = T$ thus choosing one pins down another
  - Static optimization as no multiple periods and no savings
- Assume wage w is taken as given and does not depend on H

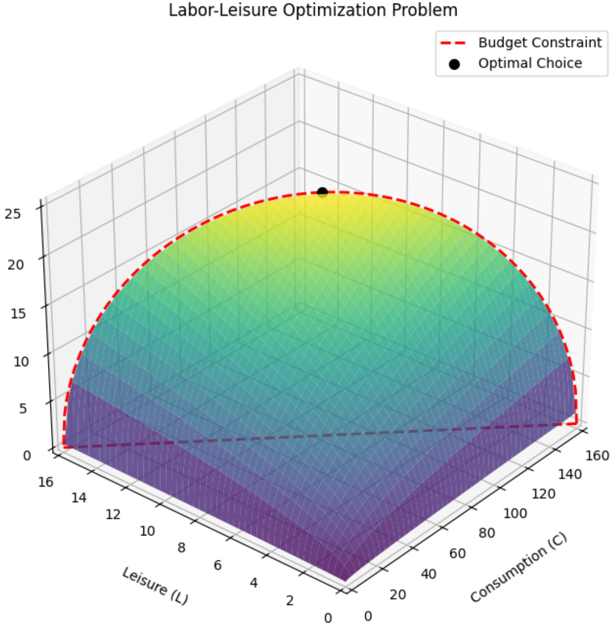
Optimization

- Problem: $\max_{C,L} U(C, L)$ subject to $C = w(T - L) + Y$
- Note the budget constraint can be also written as $Tw + Y = Lw + C$
  - $Tw + Y$ can be referred to as **"full income"**
  - The price (opportunity cost) for L is w
  - A rise in w increases both full income and cost of leisure
- Alternatively: $\max_{C,H} V(C, H) = U(C, T - H)$ s.t. $C = wH + Y$
  - Can also regard H in $V()$ as a negative term, i.e. disutility

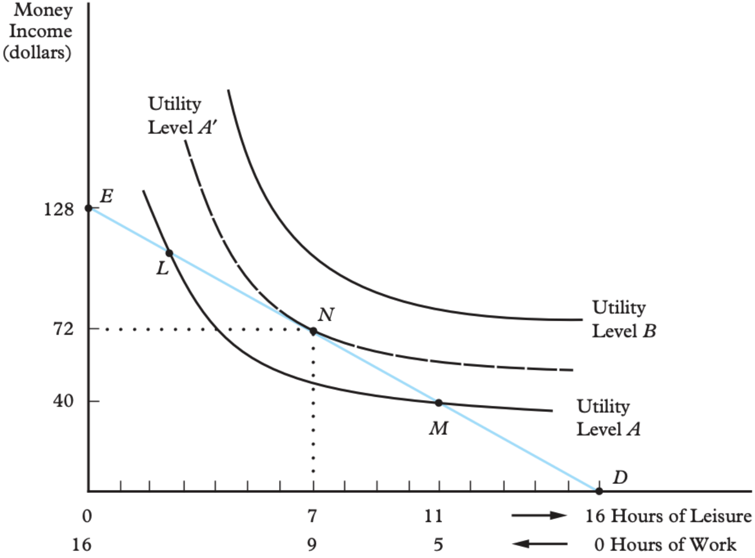
Derivation

- $\max_{C,L} U(C, L)$ s.t. $C = w(T - L) + Y$
- Lagrangian: $\mathcal{L} = U(C, L) - \lambda\,(C - w(T - L) - Y)$
- Assume an interior optimum, the First Order Conditions (FOCs):
$$\begin{aligned}\mathcal{L}_C =& U_C - \lambda = 0\\ \mathcal{L}_L =& U_L - \lambda w = 0\\ \mathcal{L}_\lambda =& C - w(T - L) - Y = 0\end{aligned}$$
- **Tradeoff**: $U_L(C^*, L^*) = wU_C(C^*, L^*)$
  - Note U_L / U_C is the marginal rate of substitution (MRS), which equates to w, the relative price
- **Marshallian (Uncompensated) Demand** functions: $\begin{array}{l} L = L^m\,(w, Y) \\ C = C^m\,(w, Y)\end{array}$
- Lagrange multiplier: $\lambda = U_C = \lambda^m\,(w, Y)$
  - Interpreted as marginal utility or ”shadow price” of income

Visualize Optimization *(see the code)*

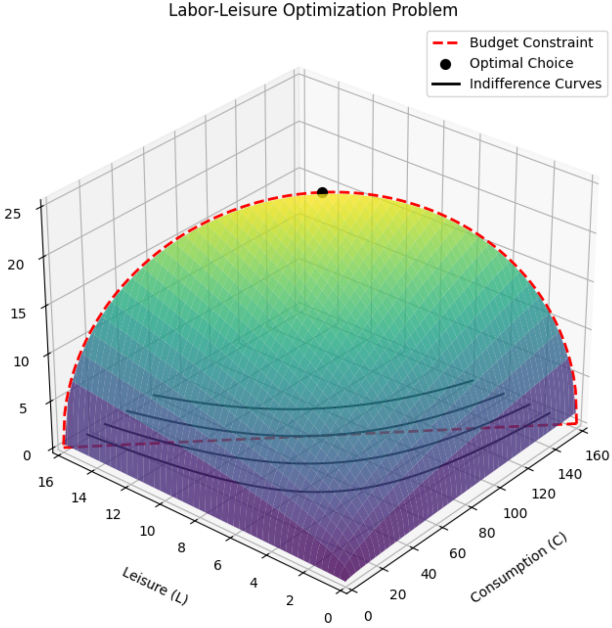


Indifference Curves and Budget Constraint Curve

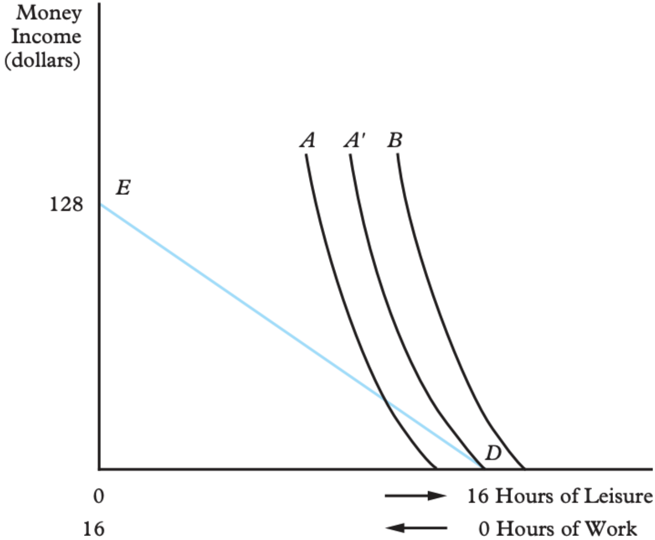


(The indifference curves bending outward (convex to origin) comes from our concavity assumption; But why we don't want it bending inward?)

IC and BC in 3D Plot

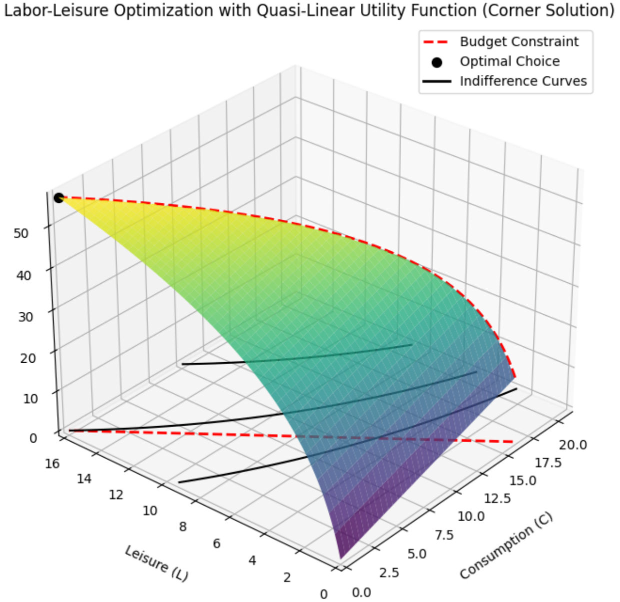


Not-Work is A Corner Solution ($U_L > wU_C$)

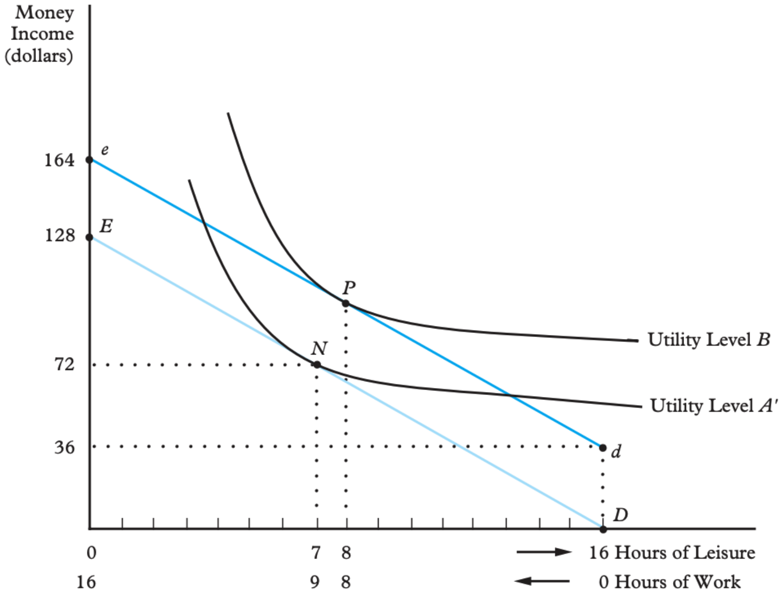


(We can define a "reservation wage" $\underline{w}$ *by* $\underline{w} = U_L(Y, T)/U_C(Y, T)$*, i.e. the wage that is just low enough to induce the agent to supply a tiny unit of labor)*

Corner Solution in 3D Plot



Income Effect (An Increase in Y)



Income Effect in Math

- Income Effect:

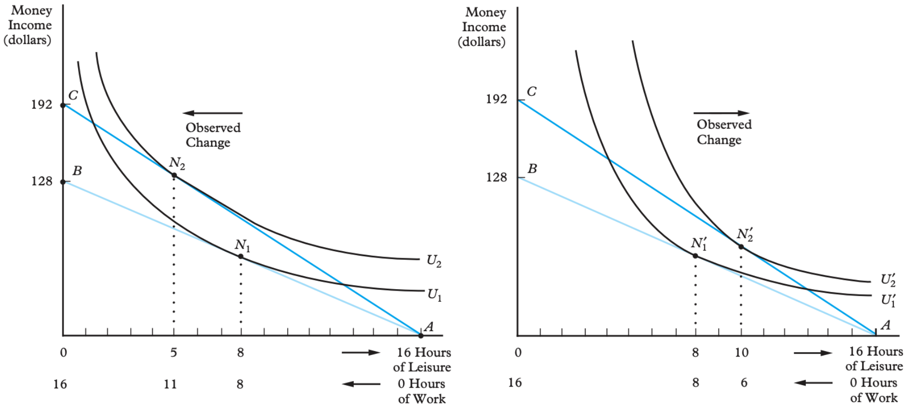
$$\frac{\partial L^m}{\partial Y}$$

- Income elasticity of leisure demand

$$\varepsilon_{L,Y} = \frac{\partial L^m}{\partial Y}\frac{Y}{L} = \frac{\partial \ln L^m}{\partial \ln Y}$$

- Leisure is generally regarded as a normal good, i.e. $0 < \varepsilon_{L,Y} \leq 1$
  - Inferior good if $\varepsilon_{L,Y} \leq 0$; Luxury good if $\varepsilon_{L,Y} > 1$
  - This means $\frac{\partial L^m}{\partial Y} > 0$
- The sign depends on the utility function used
  - E.g. CD utility functions, $U(C, L) = C^\alpha L^\beta$ with $\alpha, \beta > 0$ and $\alpha + \beta \leq 1$, imply both C and L are normal goods
- Cases of observing income effect:
  - lottery; bequest; government cash transfer

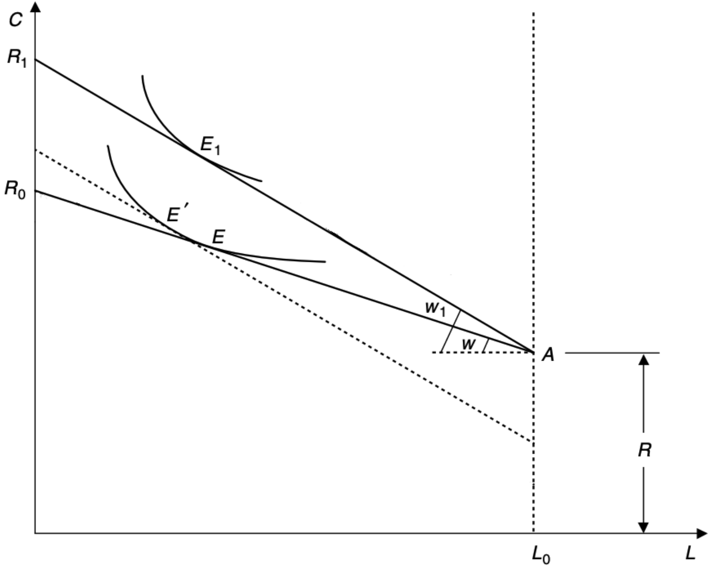
Wage Effect (An Increase in w)



(The result, again, depends on the shape of the indifference curve—i.e. the utility function!)

(It turns out that this wage change nests two effects: substitution and income effects!)

Income + Substitution Effect (An Increase in w)



Step 1: Maintain the initial utility but twist to new wage ($E \rightarrow E'$; substitution effect);

Step 2: Shift to new budget constraint and find optimal level ($E' \rightarrow E_1$; income effect)

Wage Effect in Math

- Slutsky equation:

$$\frac{\partial L^m}{\partial w} = \underbrace{\left.\frac{\partial L^h}{\partial w}\right|_U}_{\text{Substitution Effect (-)}} + \underbrace{\left.\frac{\partial L^m}{\partial Y} H^h\right|_w}_{\text{Income Effect (+)}}$$

- Elasticity form:

$$\underbrace{\varepsilon_{L,w}}_{\text{Uncompensated Elasticity}} = \underbrace{\varepsilon^c_{L,w}}_{\text{Compensated Elasticity}} + \varepsilon_{L,Y} \frac{wH}{Y}$$

- The net effect depends on the relative size of two effects
- Estimated results in the microeconomics literature are small:
  - $\varepsilon_{H,w} \in [-0.1, 0.2]$ and $\varepsilon^c_{H,w} \in [0.1, 0.3]$
- Cases of observing wage (price) effects:
  - income tax; minimum wage
  - ”Price” changes in leisure activities or home production

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The Dual Problem

(This problem helps to conduct the calculation in Step 1)

- The **dual problem** is to minimize the expenditure to achieve some utility U:
$$Y(w,U) = \min_{C,L} C - w(T-L)$$
s.t. $U(C,L) \geq U$
  - Referred as "excess expenditure function"
  - Here Y is no longer a given parameter in the budget constraint but the value of the objective function
- $\mathcal{L} = C - w(T-L) - \lambda\left(U(C,L) - U\right)$
- **Hicksian (Compensated) Demand** functions: $\begin{array}{l} C = C^h\left(w,U\right) \\ L = L^h\left(w,U\right) \end{array}$
- Expenditure function: $Y\left(w,U\right) = C^h\left(w,U\right) - w\left(T - L^h\left(w,U\right)\right)$

Derive Slutsky Equation

- Sheppard's lemma: $Y_w(w, U) = -(T - L^h(w, U)) = -H^h(w, U)$
  (*take derivative of the expenditure function and use Envelop theorem*)

- The Hicksian and Marshallian demand functions for leisure are related to each other: $L^h(w, U) \equiv L^m(w, Y(w, U))$

- Differentiating:

$$\frac{\partial L^h}{\partial w} = \frac{\partial L^m}{\partial w} + \frac{\partial L^m}{\partial Y}\frac{\partial Y}{\partial w}$$

- Slutsky equation:

$$\frac{\partial L^m}{\partial w} = \underbrace{\frac{\partial L^h}{\partial w}}_{\text{Substitution Effect (-)}} + \underbrace{\frac{\partial L^m}{\partial Y} H^h}_{\text{Income Effect (+)}}$$

(Be careful that we have rearranged the equation!)

What Do $\frac{\partial L^h}{\partial w}$ and $\frac{\partial L^m}{\partial Y}$ Depend On?

- Slutsky equation in utility terms: *(see next slide for derivation)*

$$\frac{\partial L}{\partial w} = \frac{U_C - (U_{LC} - wU_{CC})(T - L)}{U_{LL} + w^2 U_{CC} - 2wU_{LC}}$$

- The denominator is the SOC of the problem and thus negative given concavity *(see in two slides)*
- Thus $\frac{\partial L}{\partial w} \propto -U_C + (U_{LC} - wU_{CC})H$
- $-U_C$ captures the substitution effect, which is proportional to the marginal utility of consumption
- $(U_{LC} - wU_{CC})H$ captures the income effect, which depends on the cross-derivative and the concavity of the utility function in consumption
  - Now you can see why for Quasi-linear utility functions the income effect is 0 ($U_{LC} = 0$; $U_{CC} = 0$)

Derive Slutsky Equation from Utility Function

- Total differentiating $\frac{U_L}{U_C} = w$ with respect to w
- $\frac{U_C \frac{\partial U_L}{\partial w} - U_L \frac{\partial U_C}{\partial w}}{U_C^2} = 1 \Rightarrow \frac{\partial U_L}{\partial w} - \frac{U_L}{U_C}\frac{\partial U_C}{\partial w} = U_C \Rightarrow \frac{\partial U_L}{\partial w} - w\frac{\partial U_C}{\partial w} = U_C$
- $\Rightarrow U_{LL}\frac{\partial L}{\partial w} + U_{LC}\frac{\partial C}{\partial w} - w(U_{CC}\frac{\partial C}{\partial w} + U_{LC}\frac{\partial L}{\partial w}) = U_C$
- From $C = (T-L)w + Y \Rightarrow \frac{\partial C}{\partial w} = T - L - w\frac{\partial L}{\partial w}$
- $\Rightarrow U_{LL}\frac{\partial L}{\partial w} + (U_{LC} - wU_{CC})(T-L) + w^2 U_{CC}\frac{\partial L}{\partial w} - 2wU_{LC}\frac{\partial L}{\partial w} = U_C$
- $\Rightarrow \frac{\partial L}{\partial w} = \frac{U_C - (U_{LC} - wU_{CC})(T-L)}{U_{LL} + w^2 U_{CC} - 2wU_{LC}}$
- Note that you can totally differentiating w.r.t. Y to get $\frac{\partial L}{\partial Y}$, which directly gives you the formula of income effect!
  (In fact, the more general way to do all the derivations is to total differentiate FOCs w.r.t w and Y in the matrix form and then to solve the system)

Second Order Condition

- As we are dealing with constrained optimization, we examine how the objective function changes according to a vector of budget-neutral variations: $(dC, dL) = (-w, 1)dL$ (because we need $dC = -wdL$ for budget not changing)
- The second-order effect of such a variation is
  $$(-w, 1)\begin{bmatrix} U_{CC} & U_{CL} \\ U_{LC} & U_{LL} \end{bmatrix}\begin{bmatrix} -w \\ 1 \end{bmatrix} = w^2 U_{CC} - 2wU_{CL} + U_{LL} < 0$$
  - $\begin{bmatrix} U_{CC} & U_{CL} \\ U_{LC} & U_{LL} \end{bmatrix}$ is the Hessian matrix of the utility function
  - Quadratic form ($v'Qv$) here tells about the steepness or curvature of the specific path following our budget-neutral variations
  - We can prove this inequality holds with strictly quasi-concave (s.q.c) utility function (see last year's slide)
  - In fact, the concavity assumed already ensures the Hessian matrix to be negative semi-definite, i.e. the quadratic form to be negative for all non-zero vectors v
  - That's why FOCs are both necessary and sufficient to characterize an interior "preference maximal" with s.q.c!

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Why Declined Working Hours?

Boppart and Krusell (2020): $w \uparrow$ and income effect dominated!

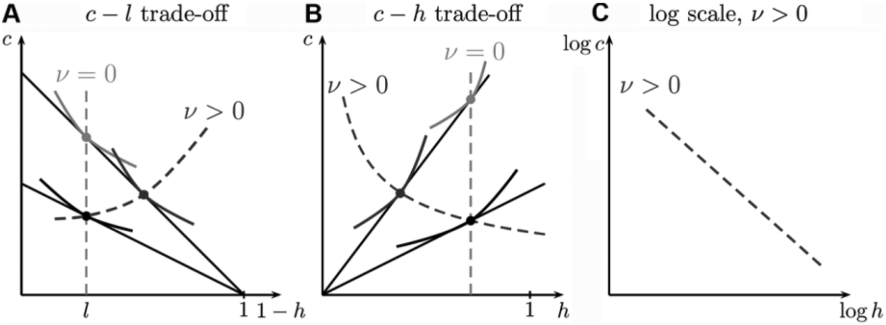
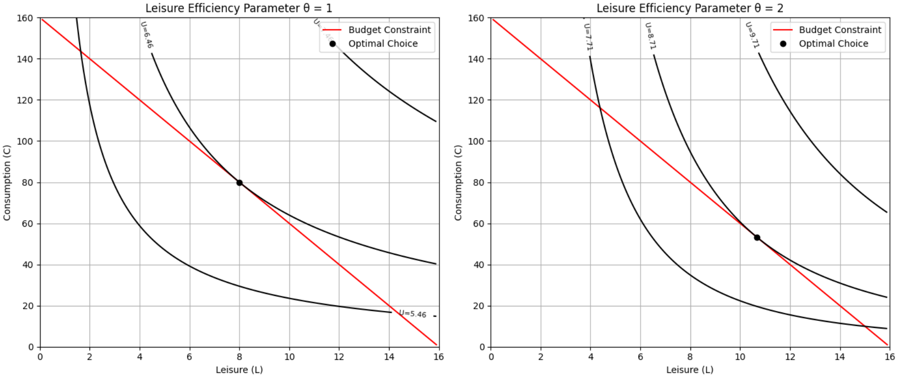


FIG. 5.—Consumption-leisure trade-off. The figure panels abstract from unearned income. A color version of this figure is available online.

(Their utility function: $u(c,h) = \frac{\left(c \cdot v\left(hc^{\nu/(1-\nu)}\right)\right)^{1-\sigma} - 1}{1-\sigma}$; with $\sigma > 1$, $\nu > 0$; $c^{\frac{\nu}{1-\nu}}$ captures a stronger income effect: an added "penalty" to working (since v is a decreasing function); They thus support the Keynes' speculation: people will work 15-hour week in the future!)

Why Declined Labor Supply for Young Men?

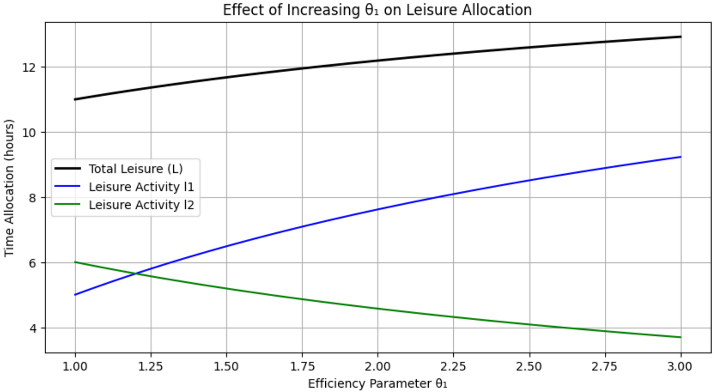
Aguiar et al. (2021): better recreational compute use and gaming increases efficiency of leisure time



(Here consider an extremely simple case: $U(C, L) = \log(C) + \theta \log(L)$ and recreational technology increases θ; Intuition: increased efficiency is similar to reduce price, generating substitutions effects)

Why Declined Labor Supply for Young Men?

Aguiar et al. (2021): *split entire leisure time into various leisure activities; find recreational computing is a "leisure luxury" for younger men*

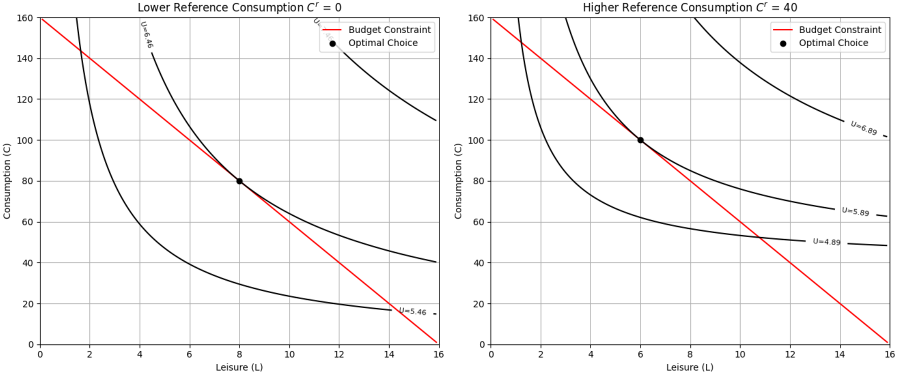


(Extend our simple utility function: $U(C, l_1, l_2) = \log(C) + \theta_1 \log(l_1) + \theta_2 \log(l_2)$*, where* $L = l_1 + l_2$*; Intuition: increased efficiency like reduced price generates "leisure income effect" and "leisure substitution effect")*

Bring Sociology into Economics

Thorsten Veblen: consumption is motivated by a desire for social standing, and other social classes strive to emulate the leisure class

Bowles and Park (2005) brings this idea into the labor-leisure framework to see how emulated consumption affect labor supply: $U = (C - C^r, L)$



(Intuition: an increase in reference consumption C^r *increases marginal utility of consumption, requiring more consumption and less leisure to balance the tradeoff)*

Roadmap

What Utility Functions Have No Income Effect?

- Quasi-linear utility: $U(C, L) = C + V(L)$
- E.g. $U(C, L) = C + \frac{L^{1+\frac{1}{\varepsilon}}}{1+\frac{1}{\varepsilon}}$
  - The optimality condition: $L^* = w^{\varepsilon}$
  - Thus the optimal choice of L^* is not a function of income (or more accurately, not a function of consumption c)
- In fact, with any quasilinear utility, we have $\frac{\partial L^m}{\partial Y} = 0$
- Intuition:
  - marginal utility of leisure is not a function of consumption
  - marginal utility of consumption is constant
- Further, $\varepsilon^u_{L,w} = \varepsilon^c_{L,w} = \partial \log L / \partial \log w = \varepsilon$
  - Thus wage elasticity of labor supply is a constant (purely through the substitution effect)

What Utility Functions Have No Wage Effect?

- Macroeconomists like to use utility functions with a form close to $u(c, l) = cv(l)$, where $v(\cdot)$ satisfies the usual conditions
- Recall FOC: $u_c w = u_l$
- $\Rightarrow v(l)w = cv'(l)$
- If there is no wealth, i.e. $y = 0$, then $c = wh = w(1 - l)$
- $\Rightarrow v(l)w = w(1 - l)v'(l) \Rightarrow v(l) = (1 - l)v'(l)$, i.e. l^* does not depend on w as income and substitution effects cancel out
- If $y > 0$, $v(l) = (1 - l + y/w)v'(l)$,
  - i.e. an increase in wage will reduce leisure as substitution effect dominates (intuition: the income effect is now smaller with $y > 0$)
  - In macro models, y and w will always grow in the same speed, so y/w is a constant and l^* will be stationary

What Utility Functions Have Declined Working Hour?

- MaCurdy (1981): $u(c,h) = \frac{c^{1-\sigma}-1}{1-\sigma} - \psi \frac{h^{1+1/\theta}}{1+1/\theta}$ $(\sigma, \theta \geq 0)$
- FOC: $wc^{-\sigma} = \psi h^{1/\theta}$
- $\Rightarrow h^* = \psi^{\frac{-1}{\sigma+1/\theta}} w^{\frac{1-\sigma}{\sigma+1/\theta}}$
- If $\sigma > 1$, h^* decreases with w increase, i.e. income effect dominates substitution effect
- If $\sigma = 1$, it return backs to previous case of perfect offsetting
  - To see this: first obtain $\frac{c^{1-\sigma}-1}{1-\sigma} = \log(c)$ when $\sigma = 1$; then take exponential of u to obtain a form of $cv(l)$
- General form studied in King et al. (1988) and Boppart and Krusell (2020)

What Explain Declined Labor Supply for Young Men?

- Aguiar et al. (2021) suggests better recreational computing and gaming

- Agent now chooses between multiple leisure activities in addition to the work-leisure tradeoff: e.g.

$$\max_{c,\{\ell_1,\ldots,\ell_I\},H} U(c, v(\boldsymbol{\ell};\boldsymbol{\theta}))$$

s.t. $c \leq wH$ and $\sum_{i=1}^{I} \ell_i + H \leq 1$, where $v(\boldsymbol{\ell};\boldsymbol{\theta}) = \sum_{i=1}^{I} \frac{(\theta_i \ell_i)^{1-(1/\eta_i)}}{1-(1/\eta_i)}$

- Opportunity cost for each leisure activity is not only wage, but also the utility from choosing other activities

- They estimate this leisure demand system and find r.c.g is a ”leisure luxury” specially for younger men
  - (1% increase in leisure time associated with about a 2.5% increase in r.c.g. time)

- While the key idea is very simple, the model derivation and estimation are nontrivial (see last year's slides)

Add Emulated Consumption into the Framework

- Assume $u = u(c^o, h) = u[(wh - vc^r), h]$
  - $c^r \equiv w^r h^r + y$ is the consumption level of some rich reference group
  - v measure the intensity of the relevant social comparisons
- Note that vc^r here plays the same role as a negative non-wage income y, i.e. a debt
- If the utility function is Quasi-linear in h, e.g. $u = \ln c^o - \delta h$
  - Optimal solution: $h^* = 1/\delta + vc^r/w$
- $dh^*/dc^r \propto -v\left(u_{c^o h} + wu_{c^o c^o}\right)$ is positive (same is dh^*/dv)
- With many income groups each of which takes the next richest group as its reference group, an increase in consumption by the top rich generates a downward cascade of Veblen effects

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