MIT 14.01: Principles of Microeconomics
Sp 2025, Lecture 10: Factor Markets

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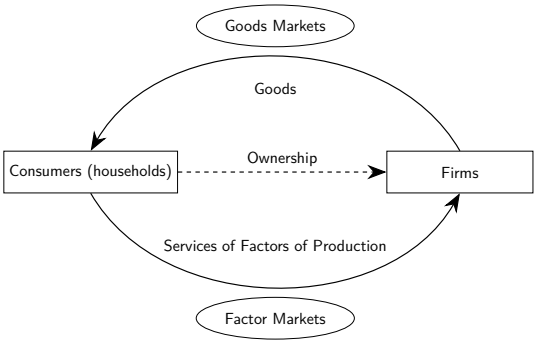
Plan for this Lecture

- Factor demand and factor market equilibrium
- Applications: Malthus, immigration, robots

Factor Markets

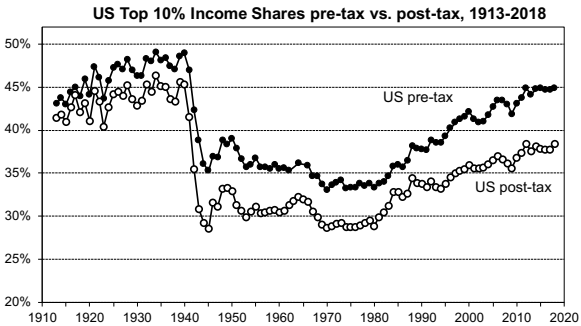
- We studied firms that require inputs ("factors of production", e.g. L and K) to produce and we took the factor prices (e.g. w and r) as exogenous
- But what determines factor prices?
- Factor prices (w, r) are determined in *factor market equilibrium* – consumers supply factors and firms demand them

How Factor Markets and Goods Markets Interact



- Solid arrows: flows of goods and services
  - From consumers to firms: selling factor services in factor markets
  - From firms to consumers: selling goods in goods markets
- In addition, consumers own firms
  - So any profits that firms make accrue back to consumers (so that consumers' total income is profit income plus payments for factor services)

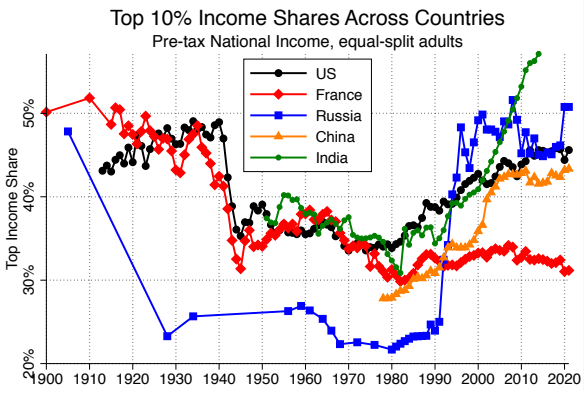
Motivation for Studying Factor Markets: How is Inequality Determined?



Piketty et al (*Q. J. Econ.*, 2018)

- People earn their incomes from selling "factor services" (e.g. supplying labor time to firms, lending firms their savings as capital)
- That process – how much of their factors they sell, and what price they get – is therefore what determines incomes
- And those incomes are increasingly unequal in the US (almost back to *Great Gatsby* levels!)

Motivation for Studying Factor Markets: How is Inequality Determined?



Piketty et al (WID.world)

- People earn their income from selling "factor services" (e.g. supplying labor time to firms, giving firms their savings as capital)
- That process – how much of their factors they sell, and what price they get – is therefore what determines incomes
- And some intriguing differences and similarities across countries...

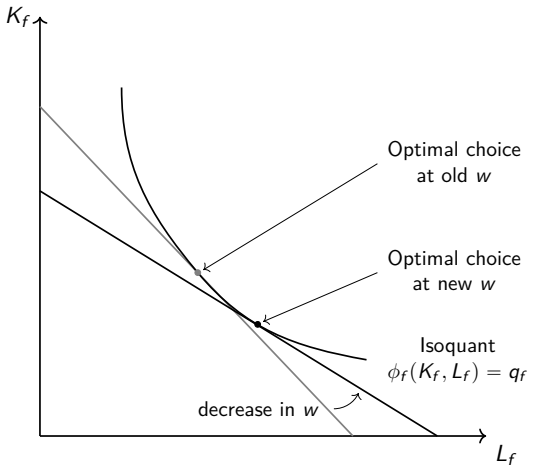
Factor Demand (e.g. Labor Demand)

- What determines factor demand? Firms demand factors because they need factors as inputs into production (in order to produce the product that consumers demand from them).
  - Sometimes also called the firms' *derived demand* for inputs
- In Lecture #8 we studied firms' demand for inputs as part of their cost-minimization problem:

$$\min_{K_f, L_f} \; wL_f + rK_f \quad \text{s.t.} \quad q_f \leqslant \phi_f(K_f, L_f) \tag{1}$$

- The solution to this problem (i.e. L_f^* and K_f^*) is the firm's *conditional demand function* for each factor. E.g. for labor we can denote it $L_f^{CD}(w, r, q_f)$.
- Key to remember that this is *conditional* on q_f
  - We have no reason whatsoever to think that this firm would hold its q_f constant if (w, r) were to change
  - But conditional factor demand is still a useful first step to thinking about actual factor demand

Conditional Factor Demand



- Suppose w falls (but r and q_f are fixed)
- Cost-minimizing isocost line rotates. Firm "slides down" the isoquant and hence uses more L_f (and less K_f)
- So conditional factor demand function (e.g. $L_f^{\text{CD}}(w, r, q_f)$) slopes downwards in own price (e.g. w)
- We call this *substitution* (of L_f for K_f)
  - Recall that the slope of the isoquant at the optimum is called the marginal rate of technical substitution (MRTS)

Unconditional Factor Demand

- Now we study *unconditional factor demand*: when q_f can (and almost always will) adjust
- This requires us to return to the firm's profit-maximization (not just cost-minimization) decision. Recall from Lecture #9 that (for a competitive firm, i.e. taking p as given) this is (assuming SOC is satisfied, and $q_f^* > 0$):

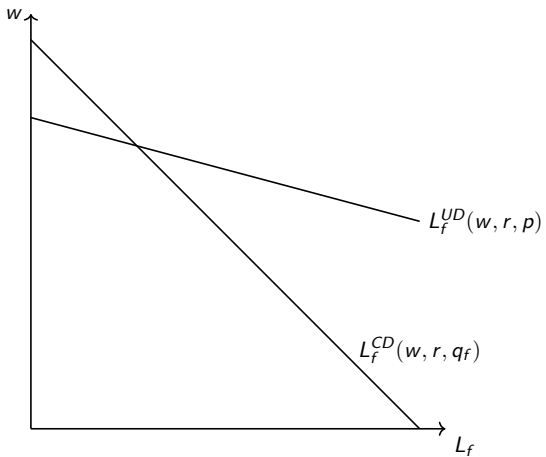
$$\max_{q_f} pq_f - C_f(w, r, q_f) \qquad \Rightarrow \qquad p = MC_f(w, r, q_f^*)$$

- And we called the solution q_f^* the firm's supply function: $q_f = S_f(w, r, p)$
- So the (competitive, i.e. with p fixed) firm's unconditional factor demand is really just the conditional factor demand $L_f^{\text{CD}}(w, r, q_f)$ evaluated at $q_f = S_f(w, r, p)$:
  - That is, $L_f^{\text{UD}}(w, r, p) \equiv L_f^{\text{CD}}(w, r, S_f(w, r, p))$

The Le Chatelier Principle

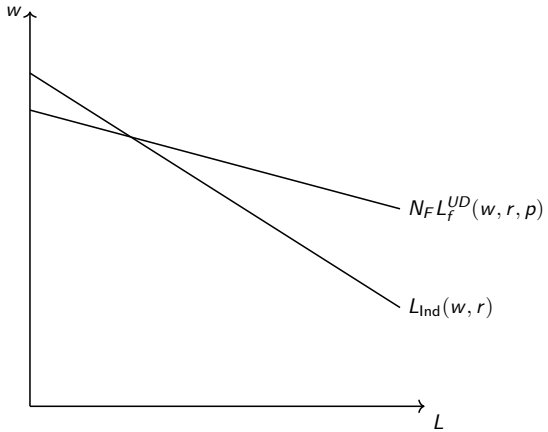
- Note how the difference between conditional and unconditional factor demand is that the former has a constraint (i.e. that q_f is fixed) imposed on the firm's problem
- Studying such situations invokes a general idea (called the *Le Chatelier Principle*) that is useful in economics:
  - Take any (potentially constrained) optimization problem and make it strictly less constrained
  - Then the resulting optimal solution to the new (i.e. less constrained) problem will be more price-elastic (in absolute value, and with the same sign) than the solution to the original (i.e. more constrained) problem
- So unconditional factor demand is more elastic than conditional factor demand, but still downward-sloping

Unconditional Factor Demand



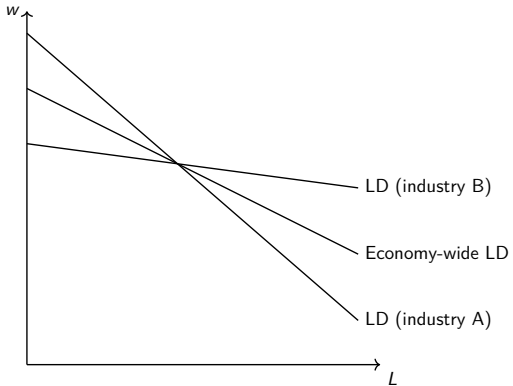
- *Substitution effect*: the slope of the conditional factor demand curve
- *Scale effect*: the difference between the conditional and unconditional factor demand curves (i.e. the bit that is due to adjusting scale, q_f)
- Both the substitution and scale effects are the same sign (i.e. both contribute to downward-sloping demand, $\frac{\partial L_f^{UD}}{\partial w} < 0$)
- And by the Le Chatelier Principle, unconditional factor demand is more elastic (in absolute value) so: $\left|\frac{\partial L_f^{UD}}{\partial w}\right| > \left|\frac{\partial L_f^{CD}}{\partial w}\right|$

Industry-level Unconditional Factor Demand



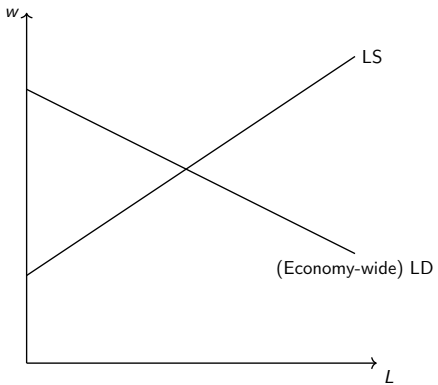
- Now consider the total (unconditional) factor demand by a group of N_F identical firms who all make the same thing (i.e. are in the same "industry"). Aggregate labor demand is $N_F L_f^{UD}(w, r, p)$ at fixed p.
- But when w falls and all firms use more L_f and hence expand their q_f, we expect p to fall (assuming the demand the firms face for their product $D(p)$ is downward-sloping)
  - This effect will be stronger when $D(p)$ is more inelastic
- This will dampen (but not change the sign of) the scale effect, so industry-level factor demand $L_{\text{Ind}}(w, r)$ is still downward-sloping

Total Economy-Wide Factor Demand



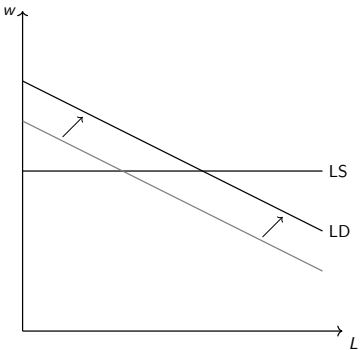
- Now suppose we are interested in the total factor demand by all industries in the economy
- This economy-wide factor-demand function will be an (appropriately size-weighted) average of the industry-level factor demand functions for all the industries
- Since all industry-level factor demand functions are downward-sloping, the economy-wide factor demand function will therefore also be downward-sloping in its own price

Factor Market Equilibrium



- Can now put total (economy-wide) factor demand and supply together
- Could have a *competitive factor market equilibrium* in the L and K markets
  - Individual firms demanding, and individual households supplying, factors all too small for their individual actions to affect (w, r)
- This equilibrium then determines (w, r), where $LS(w) = LD(w)$ etc.
- Well, not quite....where does consumer demand $D(p)$ come from?
  - Consumers may get their incomes y_i from selling labor and capital then we need to make $D(p)$ a function of (w, r) too
  - We'll get there!

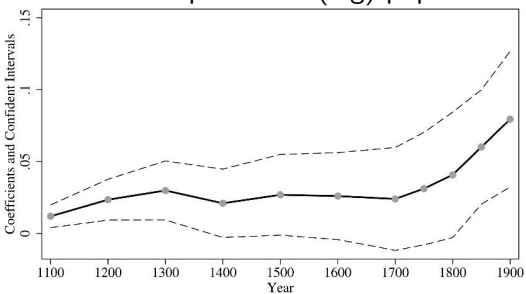
A Malthusian Factor Market Equilibrium



- Thomas Malthus (c. 1798) thought that aggregate labor supply was approximately perfectly elastic. Why?
  - Fertility: if wages go up above "subsistence" levels, people will just have more food and hence be able to afford to have more kids
  - Mortality/morbidity: if wages go below "subsistence" levels, people will eat too little and hence live shorter/unhealthier lives
- Pretty shocking implication:
  - Suppose someone discovers a way to increase labor productivity (and so push out LD curve)
  - Would result in more people ($\Delta L > 0$) but no increase in per-capita living standards ($\Delta w = 0$)
  - This observation earned the name of "the dismal science"!
- Following this thinking, Malthus was opposed to giving aid to the poor in England (or during famines in India)

Was Malthus Right?

Effects of the potato on (log) population

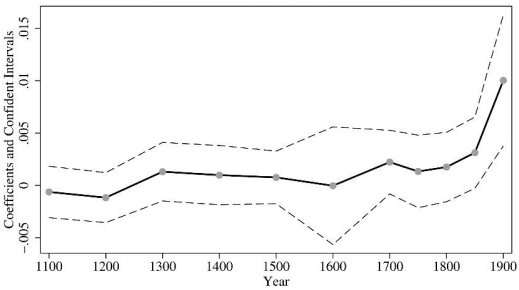


Nunn and Qian (*Q. J. Econ.*, 2011)

- Europe's discovery of N. and S. America brought the potato to Europe and Asia around 1700
  - Was a huge boost (in regions of Europe/Asia with suitable soil/climate) to land productivity (calories per acre)
- This figure reports estimates of how (log) population differed, in each year, across regions of Europe/Asia that are relatively more vs. less potato-suitable
- The response of increased population (L) to increased land productivity (i.e. LD) around 1700 is exactly what Malthus predicted

Was Malthus Right?

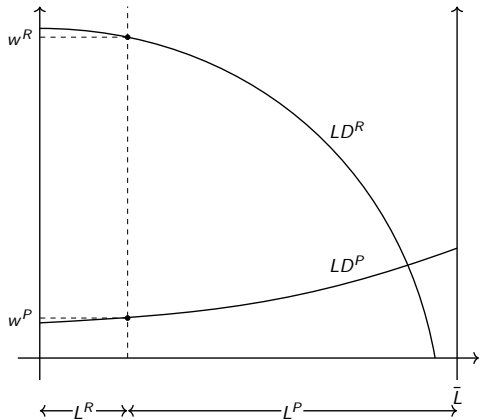
Effects of the potato on log (urbanization)



Nunn and Qian (*Q. J. Econ.*, 2011)

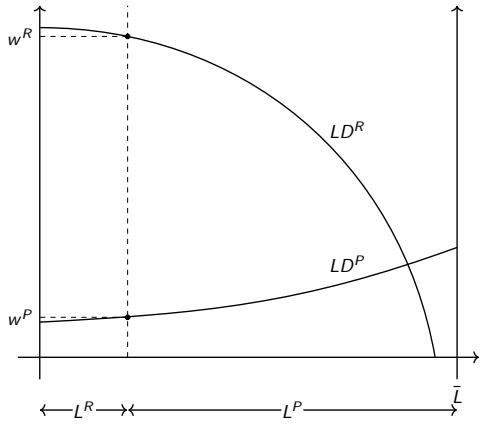
- This figure is the same, but now looks at the urbanization rate (a proxy for per-person living standards, i.e. w)
- Pre-1850, Malthus was right! No effect of LD on w.
- Post-1850, Malthus was wrong! Big effect of LD on w.
- Evidently, for some reason (still debated), labor supply became less elastic around the Industrial Revolution (i.e. c. 1850)
- One theory: *human capital* became valuable, so families were more likely to invest in kids rather than having more kids

What Are the Effects of Immigration?



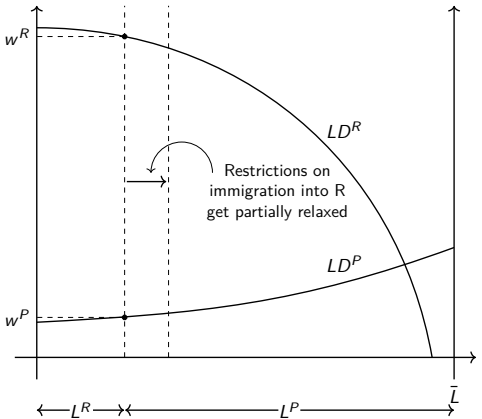
- Suppose there are two countries: rich (R) and poor (P)
- Drawn here:
  - LD in R (i.e. LD^R) is downward sloping as usual
  - LD in P (i.e. LD^P) we measure in the opposite direction (so it's also downward-sloping when measured from right to left)
  - We do this so that we can impose the world's "adding up" constraint: the total amount of labor in the world ($\bar{L}$) is either used in R (L^R) or in P (L^P), so $\bar{L} = L^R + L^P$ always holds
- R has better technology/capital, so its LD curve is higher

What Are the Effects of Immigration?



- At the illustrated L^R and L^P allocation, $w^R > w^P$
- What you are looking at here may be the largest deadweight loss "triangle" in human history:
  - E.g. think of "R" as top 10% of global income, and "L" as bottom 10%. So $w^R \approx \$30,000$, $w^L \approx \$200$ per year, as we saw in Lecture #1.
  - $\Rightarrow$ height: \$29,800 per person per year
  - $\Rightarrow$ base: almost 90% of humanity ??
  - $\Rightarrow$ triangle (per year per person globally): $= (0.5) \times (0.9)(\$29.8K) = \$13.4K =$ roughly as big as total world GDP per capita (\$12K-\$15K)

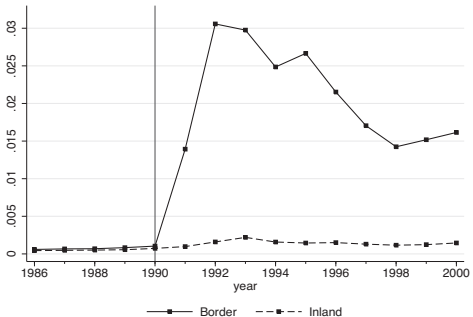
What Are the Effects of Immigration?



- At the illustrated L^R and L^P allocation, $w^R > w^P$
- We would therefore expect labor to try to move from P to R (to arbitrage away that difference in the price they can get from selling their factor services)
- Suppose that flow is restricted. But then those restrictions are relaxed somewhat (as illustrated here). What will happen?

What Are the Effects of Immigration?

Employment share of Czech nationals

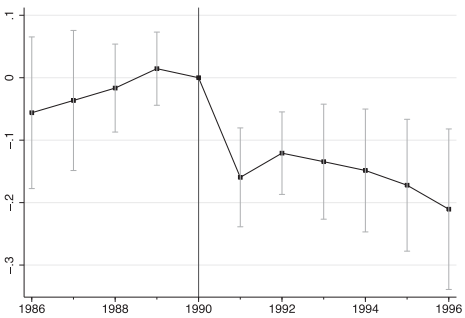


Dustmann et al (*Q. J. Econ.*, 2017)

- In 1991, after the fall of the Iron Curtain, Germany allowed immigration/commuting by residents of Czech Republic
- This figure: much larger growth of Czech employment in regions of (formerly West) Germany that border Czech Republic than those that are more "inland" (i.e. further from that border)

What Are the Effects of Immigration?

Effects on native Germans' wages



Dustmann et al (*Q. J. Econ.*, 2017)

- This figure: a difference-in-differences analysis comparing wages (of native Germans) in "border" (with Czech Republic) and "inland" (further from Czech Republic) regions of Germany
- Evidence for a (v. small: - 0.2%) negative effect of inbound immigration on the wages of native Germans in the area. Caveats:
  - Most Czechs were commuters. May have taken most of their earnings back home to spend (i.e. limited induced product demand effect here, in Germany)
  - German firms may have thought this was temporary, so didn't invest much in K increases; this would make the wage drops larger than otherwise.

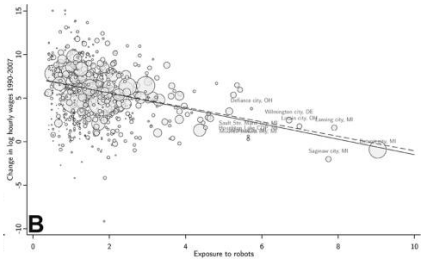
Cross-Price Elasticity of Factor Demand

What will happen to total labor demand $LD(w, r)$ when r falls? Two effects:

1. A *substitution effect* (decreases the demand for L as r falls, a force for $\frac{\partial LD}{\partial r} > 0$):
   - Every firm slides along their isoquant at fixed q_f – increasing K (now cheaper) and decreasing L (now relatively more expensive)
   - NB: with 2 inputs, this sign of this effect is clear. But with > 2 (e.g. A,B,C) inputs it can happen that lowering w_A actually raises demand for B even when q_f is fixed.
2. A *scale effect* (increases the demand for labor as r falls, a force for $\frac{\partial LD}{\partial r} < 0$):
   - Cheaper K makes firms expand their q_f, so use more L
   - Though this is dampened at the industry/economy-wide level by downward-sloping consumer demand $D(p)$ for the products being produced

- So either $\frac{\partial LD}{\partial r} < 0$ or $\frac{\partial LD}{\partial r} > 0$ is possible
  - When $\frac{\partial LD}{\partial r} > 0$ we say that K is a *gross substitute* for L (and *gross complement* when $\frac{\partial LD}{\partial r} < 0$)
  - More likely to get $\frac{\partial LD}{\partial r} < 0$ when scale effect big (i.e. when consumer demand $D(p)$ is very elastic)

The Rise of the Robots



Acemoglu and Restrepo (*J. Pol. Econ.*, 2020)

- Cheaper industrial robots over 1990-2007 period can be thought of as a drop in r – what effect did this have on wages w in the US?
- This figure:
  - x-axis: how "exposed" each US city (a circle here) was to industrial robots on the basis of its 1990 industrial composition and the intensity with which each industry uses robots
  - y-axis: change in wages w from 1990-2007
- Evidence here suggests that $\frac{\partial LD}{\partial r} > 0$, assuming the LS curve is upward-sloping
  - Perhaps especially surprising given that we expect relatively small regions like these to be quite open to trade with other regions, and hence have quite elastic consumer demand (i.e. large scale effects)

Concluding Remarks

- **Key Concepts from today's lecture:**
  - Conditional factor demand: when output quantity held constant
  - Unconditional factor demand: when output quantity flexible (but output price held constant)
  - Industry-level factor demand: when the output price adjusts
  - Economy-wide factor demand: average of industry-level factor demand across all industries
  - Le Chatelier principle: relaxing constraints makes functions more elastic (in absolute value)
  - Malthusian economy: when perfectly elastic labor supply, so effects of technological progress affect L but not w
  - Cross-price effects on factor demand: race between substitution and scale effects

- **Next lecture:**
  - Putting factor and goods markets together: general equilibrium