A. COSTINOT (MIT) AND I. WERNING (MIT)

ROBOTS, TRADE, & LUDDISM

A SUFFICIENT STATISTICS APPROACH TO OPTIMAL TECHNOLOGY REGULATION

MOTIVATION

MOTIVATION

- **Technological Progress:** Efficiency (+) vs. Inequality (-)

MOTIVATION

- **Technological Progress:** Efficiency (+) vs. Inequality (-)
  - Rise of Robots (Acemoglu and Restrepo 2017)

MOTIVATION

- **Technological Progress:** Efficiency (+) vs. Inequality (-)
  - Rise of Robots (Acemoglu and Restrepo 2017)
  - Rise of China (Autor, Dorn and Hanson 2013)

MOTIVATION

- **Technological Progress:** Efficiency (+) vs. Inequality (-)
  - Rise of Robots (Acemoglu and Restrepo 2017)
  - Rise of China (Autor, Dorn and Hanson 2013)

MOTIVATION

- **Technological Progress:** Efficiency (+) vs. Inequality (-)
  - Rise of Robots (Acemoglu and Restrepo 2017)
  - Rise of China (Autor, Dorn and Hanson 2013)
- **Questions:**

MOTIVATION

- **Technological Progress:** Efficiency (+) vs. Inequality (-)
  - Rise of Robots (Acemoglu and Restrepo 2017)
  - Rise of China (Autor, Dorn and Hanson 2013)

- **Questions:**
  1. When is technological progress welcome?

MOTIVATION

- **Technological Progress:** Efficiency (+) vs. Inequality (-)
  - Rise of Robots (Acemoglu and Restrepo 2017)
  - Rise of China (Autor, Dorn and Hanson 2013)

- **Questions:**
  1. When is technological progress welcome?
  2. How should government policy respond?

MOTIVATION

- **Technological Progress:** Efficiency (+) vs. Inequality (-)
  - Rise of Robots (Acemoglu and Restrepo 2017)
  - Rise of China (Autor, Dorn and Hanson 2013)

- **Questions:**
  1. When is technological progress welcome?
  2. How should government policy respond?

Today: bridge theory with empirics to answer these policy questions

BACKGROUND

- **First Best:** Second Welfare Theorem
  - Lump-sum transfers ⇒ Redistribution without distortions
- **Second Best:** Diamond and Mirrlees (1971)
  - Unconstrained linear taxation ⇒ Production efficiency
  - No trade taxes; no taxes on robots

THIS PAPER

- **More realistic, restricted set of tax instruments**
  - Nonlinear income tax + tax on robots/trade
  - before tax wages affected by policy (Naito 1999)
  - Predistribution vs. Redistribution
- **General framework**
  - Common principles: robots & trade
  - Theory delivers relevant sufficient statistics

RESULTS

1. When is technological change welcome?

2. How should government policy respond?

RESULTS

1. When is technological change welcome?
    - Like in a first best world (despite not being first best)
        - No taxation of innovation
        - Impact of trade only depends on TOT
2. How should government policy respond?

RESULTS

1. When is technological change welcome?
    - Like in a first best world (despite not being first best)
        - No taxation of innovation
        - Impact of trade only depends on TOT
2. How should government policy respond?
    - Formulas with sufficient statistics…

      t = function of observable elasticities and shares*

    - More robots/more trade may lower optimal taxes

RESULTS

1. When is technological change welcome?
   - Like in a first best world (despite not being first best)
     - No taxation of innovation
     - Impact of trade only depends on TOT
2. How should government policy respond?
   - Formulas with sufficient statistics…

     t = function of observable elasticities and shares*

     Key sufficient statistic = elasticity effect on relative wages
   - More robots/more trade may lower optimal taxes

RELATED LITERATURE

- **Optimal Taxation**
  - Diamond-Mirrlees, Dixit-Norman
  - Naito, Guesnerie, Spector, Jacobs
  - Mayer-Riezman, Feenstra-Lewis, Rodrik, Helpman, Grossman-Helpman, Hosseini-Shourideh
- **Welfare impact of technological progress:**
  - Solow, Hulten, Bhagwati, Baeqee-Farhi
- **Optimal tax on robots:** Guerreiro-Rebelo-Teles, Thuemmel

ROADMAP

- General Framework
- When Is Technological Change Welcome?
- How Should Government Policy Respond?
- Application to Robots and Trade

GENERAL FRAMEWORK

$\theta \sim F(\theta)$ multidimensional skills allowed (e.g. Roy Model)

$\theta \sim F(\theta)$ multidimensional skills allowed (e.g. Roy Model)

$$U = u(C, n)$$

$$C = v(\{c_i\})$$ weak separability

$\theta \sim F(\theta)$ multidimensional skills allowed (e.g. Roy Model)

$$U = u(C, n)$$

$$C = v(\{c_i\})$$ weak separability

$$G(\{y_i\}, \{n(\theta)\}) \leq 0$$

$\theta \sim F(\theta)$ multidimensional skills allowed (e.g. Roy Model)

$$U = u(C, n)$$

$$C = v(\{c_i\})$$ weak separability

$$G(\{y_i\}, \{n(\theta)\}) \leq 0$$

$$G^*(\{y_i^*\}; \phi) \leq 0$$

$\theta \sim F(\theta)$ multidimensional skills allowed (e.g. Roy Model)

$$U = u(C, n)$$

$$C = v(\{c_i\})$$ weak separability

$$G(\{y_i\}, \{n(\theta)\}) \leq 0$$

without loss of generality!

$$G^*(\{y_i^*\}; \phi) \leq 0$$

$\theta \sim F(\theta)$ multidimensional skills allowed (e.g. Roy Model)

$$U = u(C, n)$$

$C = v(\{c_i\})$ weak separability

$$G(\{y_i\}, \{n(\theta)\}) \leq 0$$

without loss of generality!

$$G^*(\{y_i^*\}; \phi) \leq 0$$

$$y_i + y_i^* = \int c_i(\theta) dF(\theta)$$

$\theta \sim F(\theta)$ multidimensional skills allowed (e.g. Roy Model)

$$U = u(C, n)$$

$C = v(\{c_i\})$ weak separability

$$G(\{y_i\}, \{n(\theta)\}) \leq 0$$

without loss of generality!

$$G^*(\{y_i^*\}; \phi) \leq 0$$

$$y_i + y_i^* = \int c_i(\theta) dF(\theta)$$

TRADE EXAMPLE

$$G^*(\{y_i^*\}; \phi) = \sum \bar{p}_i(\phi) y_i^*$$

$\theta \sim F(\theta)$ multidimensional skills allowed (e.g. Roy Model)

$$U = u(C, n)$$

$C = v(\{c_i\})$ weak separability

$$G(\{y_i\}, \{n(\theta)\}) \leq 0$$

without loss of generality!

$$G^*(\{y_i^*\}; \phi) \leq 0$$

$$y_i + y_i^* = \int c_i(\theta) dF(\theta)$$

TRADE EXAMPLE

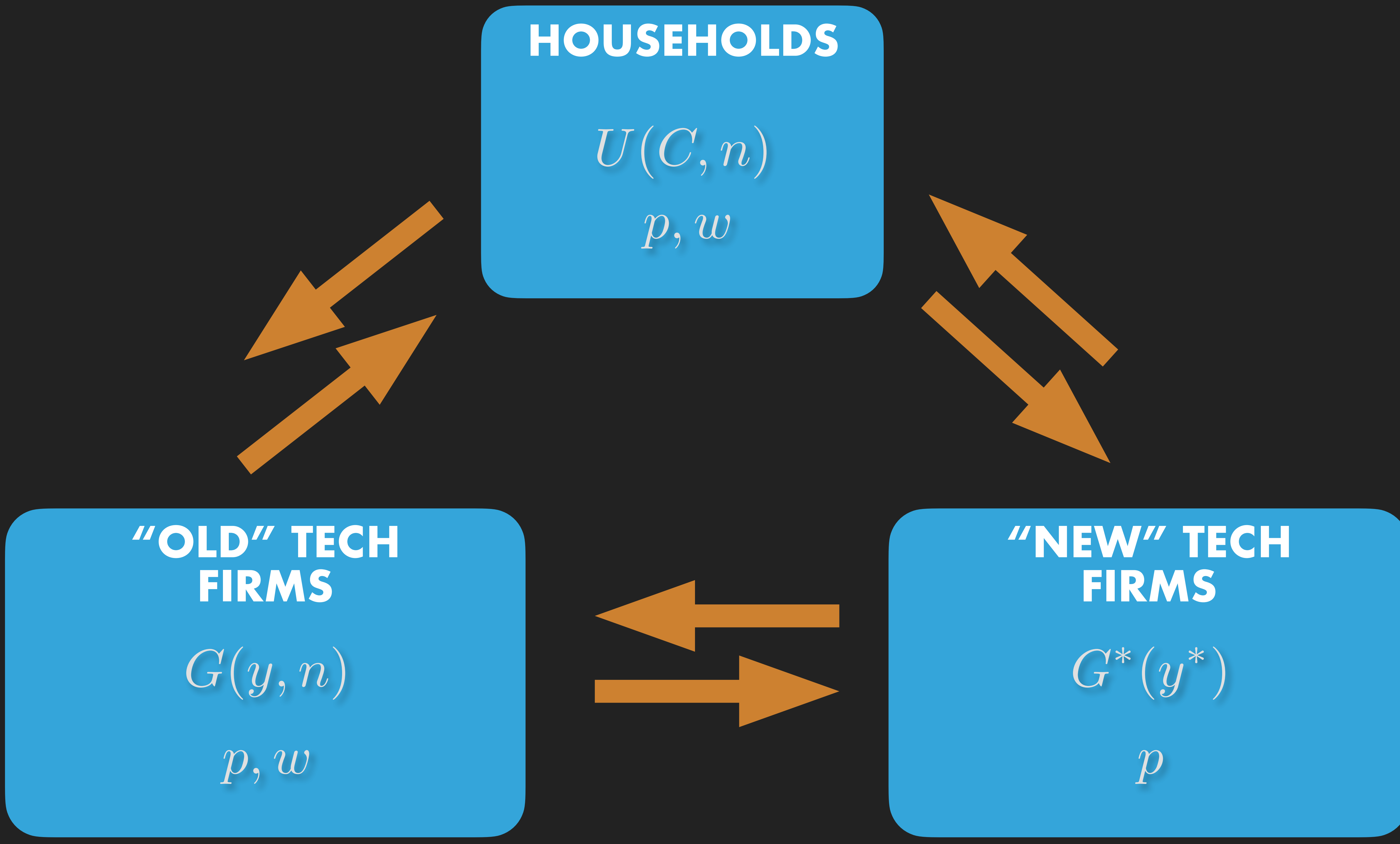
$$G^*(\{y_i^*\}; \phi) = \sum \bar{p}_i(\phi) y_i^*$$

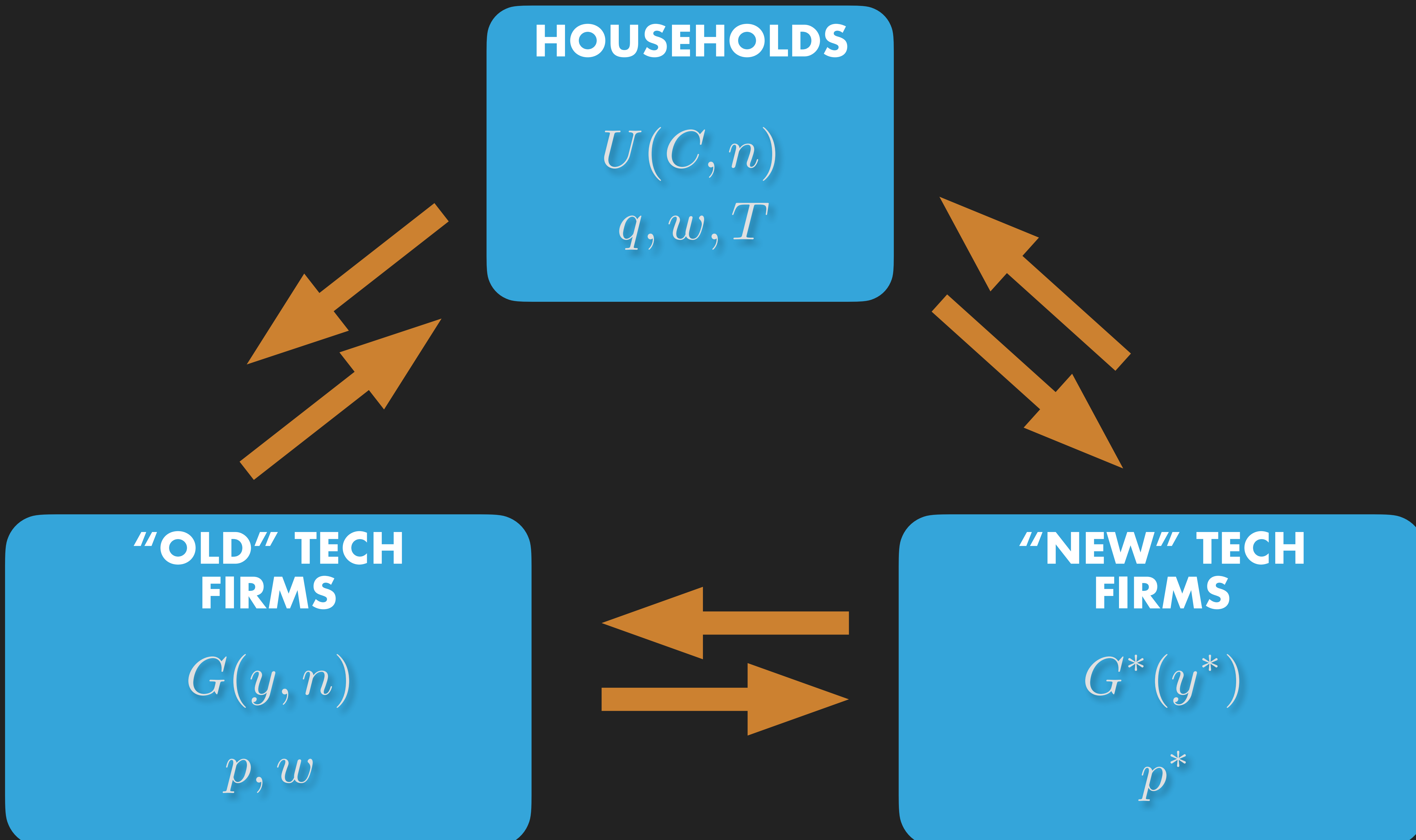
ROBOT + TASKS

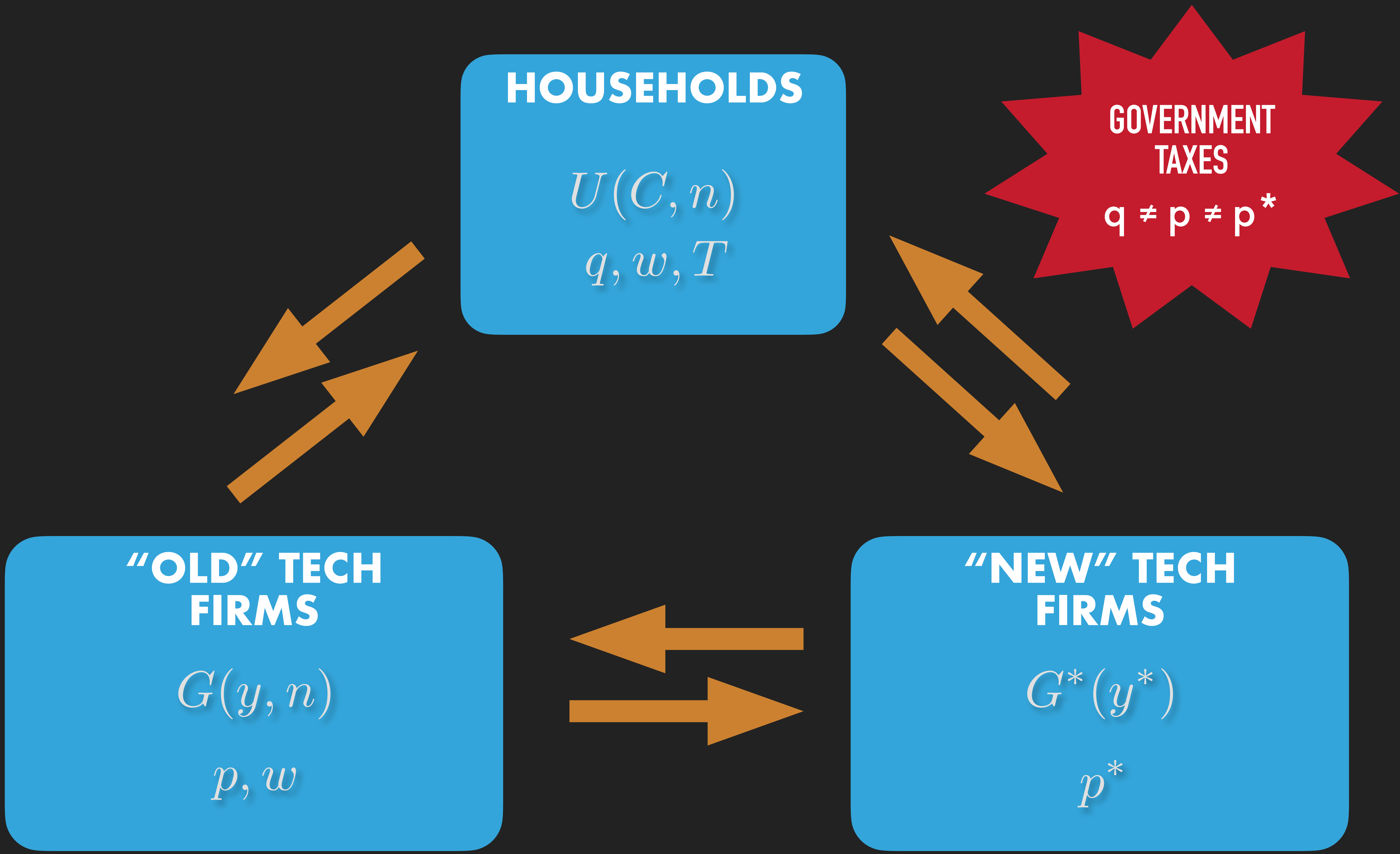
$$G^*(y_f^*, y_m^*) = \phi y_f^* + y_m^*$$

$$y_f^* = \Big(\int y_i^{*\rho} \Big)^{\frac{1}{\rho}}$$

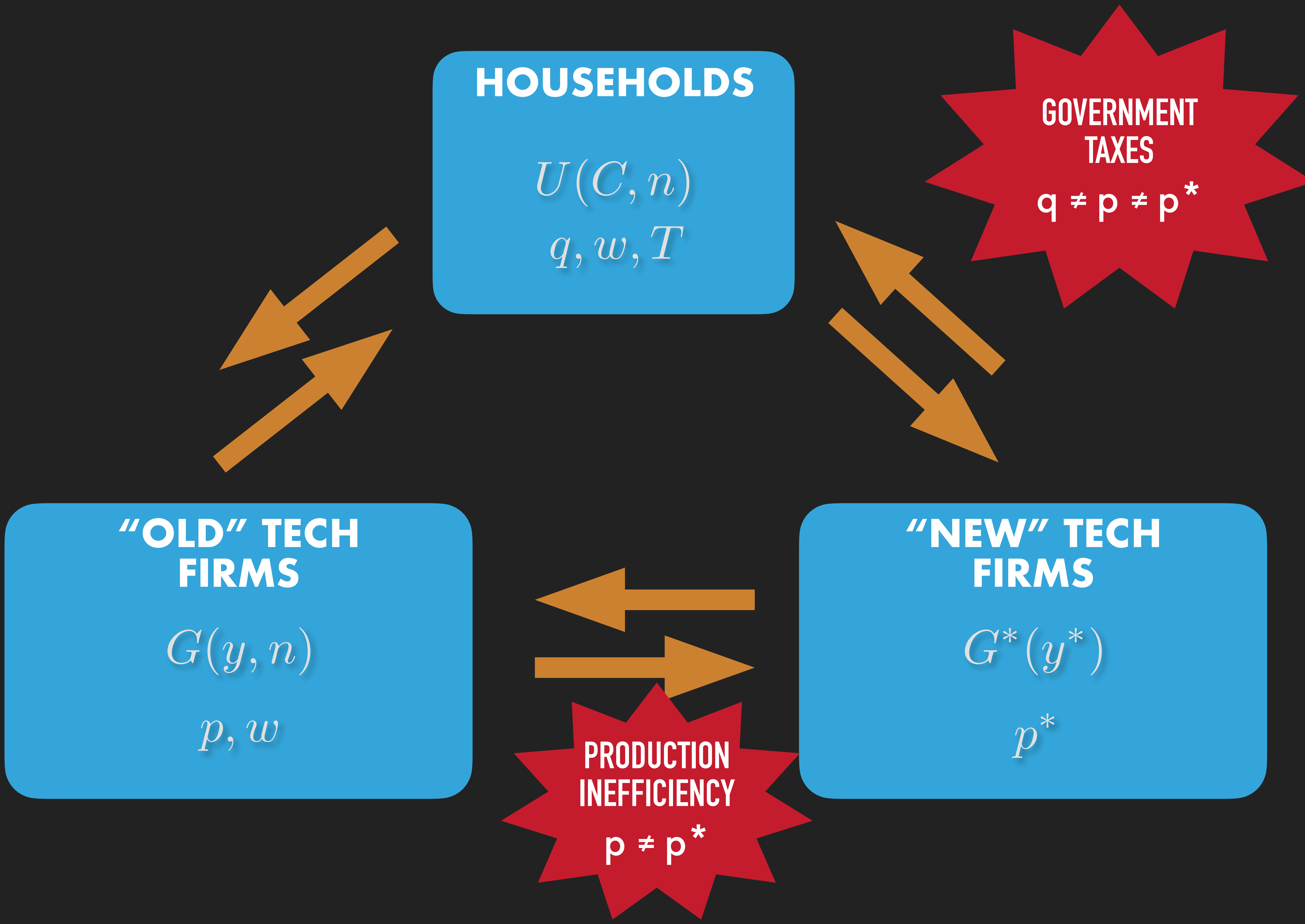
$$y_i^* = a_i(\theta) n(\theta) d\theta + a_i(r) y_r^*$$


HOUSEHOLDS
$U(C, n)$
p, w
"OLD" TECH FIRMS
$G(y, n)$
p, w
"NEW" TECH FIRMS
$G^*(y^*)$
p


HOUSEHOLDS
$U(C, n)$
q, w, T
"OLD" TECH FIRMS
$G(y, n)$
p, w
"NEW" TECH FIRMS
$G^*(y^*)$
p^*



HOUSEHOLDS
$U(C, n)$
q, w, T
GOVERNMENT
TAXES
q ≠ p ≠ p*
"OLD" TECH
FIRMS
$G(y, n)$
p, w
"NEW" TECH
FIRMS
$G^*(y^*)$
p^*


HOUSEHOLDS
$U(C, n)$
q, w, T
GOVERNMENT TAXES
q ≠ p ≠ p*
"OLD" TECH FIRMS
$G(y, n)$
p, w
"NEW" TECH FIRMS
$G^*(y^*)$
p^*
PRODUCTION INEFFICIENCY
p ≠ p*

TAXATION

- Household budget

$$\sum p_i c_i = w(\theta)n(\theta) - T(w(\theta)n(\theta))$$

TAXATION

- Household budget

Labor Income Taxation

$$\sum p_i c_i = w(\theta)n(\theta) - T(w(\theta)n(\theta))$$

TAXATION

- Household budget

Labor Income Taxation

$$\sum p_i c_i = w(\theta)n(\theta) - T(w(\theta)n(\theta))$$

- Firms profits
  - Old Technology

$$\sum p_i y_i - \int w(\theta)n(\theta)dF(\theta)$$

  - New Technology

$$\sum p_i^* y_i^*$$

TAXATION

- Household budget

Labor Income Taxation

$$\sum p_i c_i = w(\theta)n(\theta) - T(w(\theta)n(\theta))$$

- Firms profits
  - Old Technology

$$\sum p_i y_i - \int w(\theta)n(\theta)dF(\theta)$$

  - New Technology

$$\sum p_i^* y_i^*$$

- Taxes t^* :

$$p_i = (1 + t_i^*)p_i^*$$

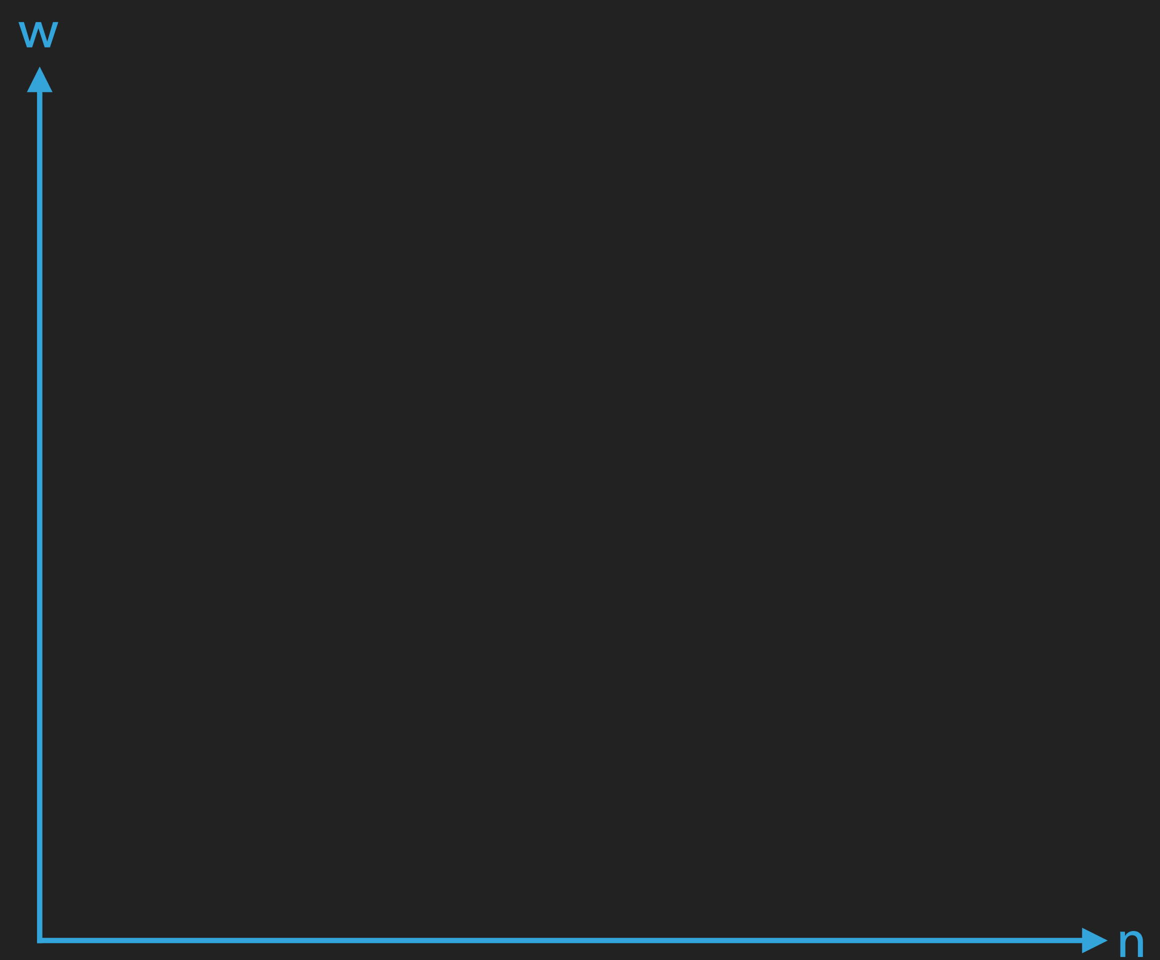
EQUILIBRIUM WAGES

- Crucial point…
  - Labor demand

    $$n^D(\{w(\theta)\}, \{p_i\}, \theta)$$

  - Equilibrium wages…

    $$w(\{p_i\}, \{n(\theta)\}, \theta)$$



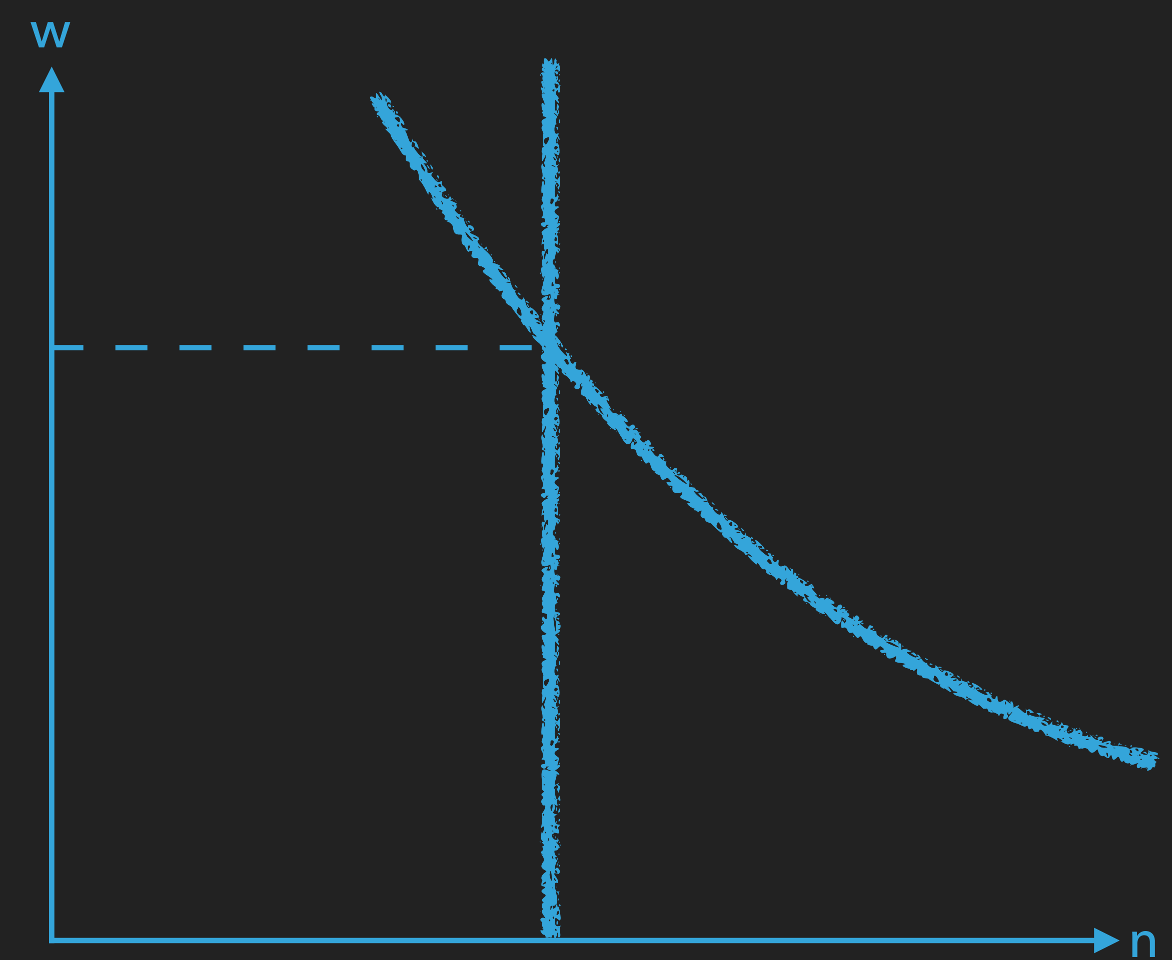
EQUILIBRIUM WAGES

- Crucial point…
  - Labor demand

$$n^D(\{w(\theta)\}, \{p_i\}, \theta)$$

  - Equilibrium wages…

$$w(\{p_i\}, \{n(\theta)\}, \theta)$$



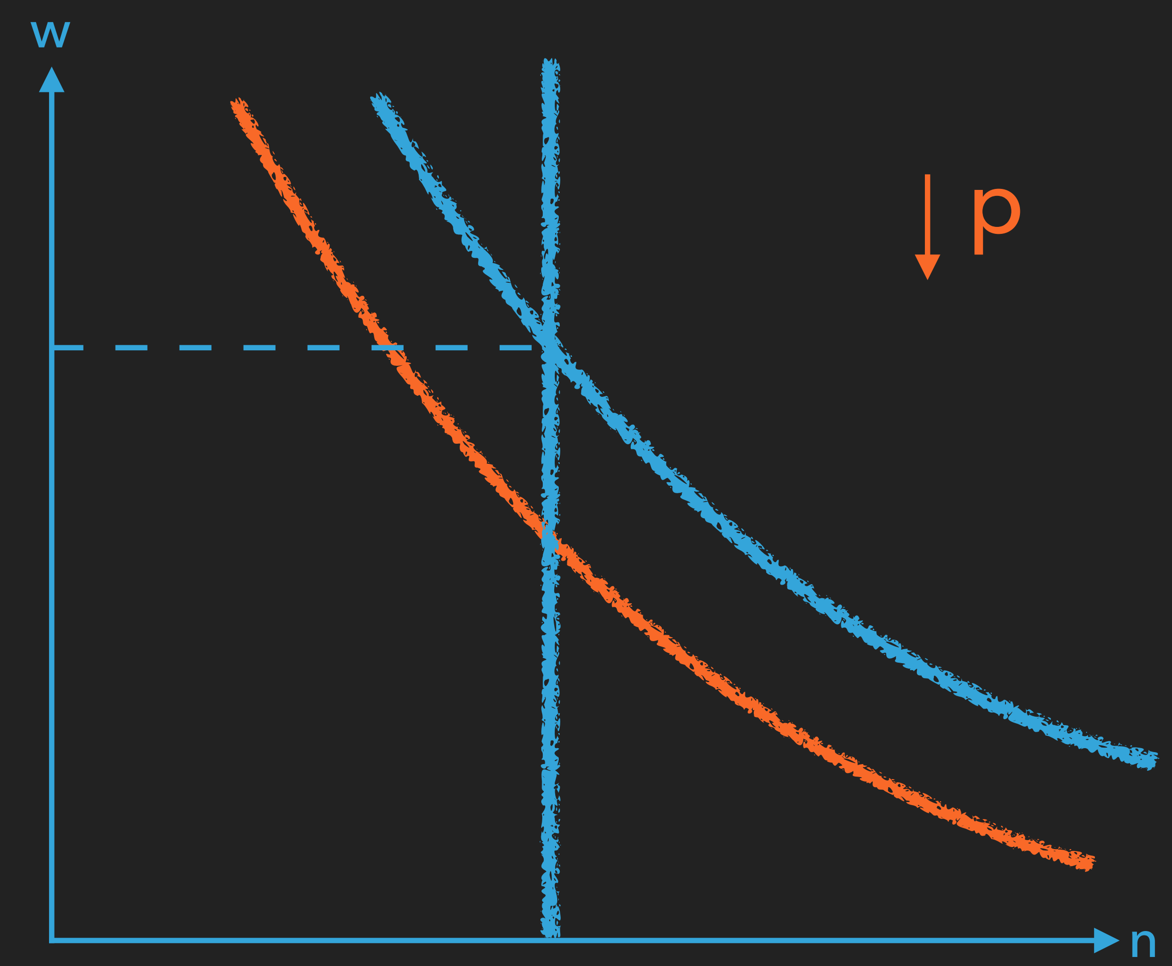
EQUILIBRIUM WAGES

- Crucial point…
  - Labor demand

    $$n^D(\{w(\theta)\}, \{p_i\}, \theta)$$

  - Equilibrium wages…

    $$w(\{p_i\}, \{n(\theta)\}, \theta)$$



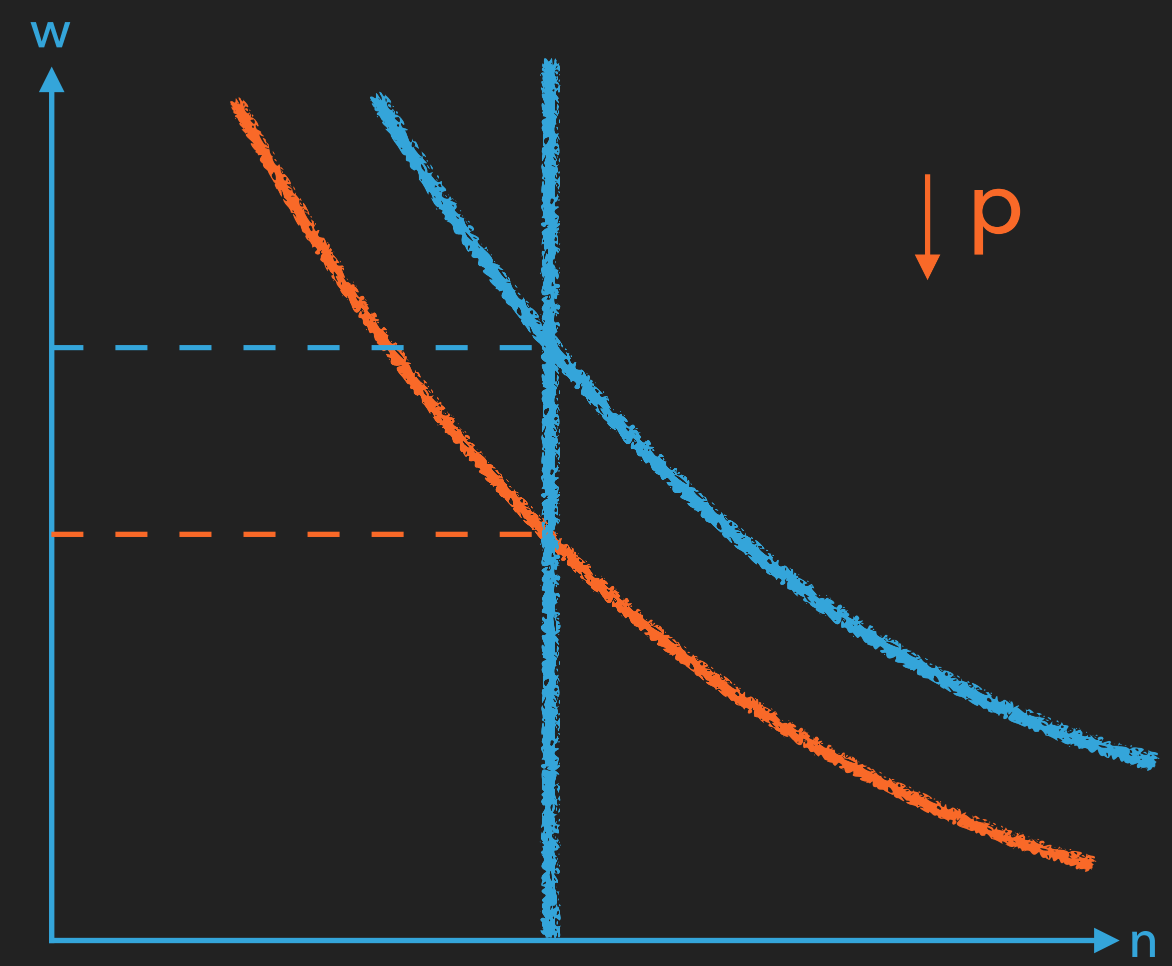
EQUILIBRIUM WAGES

- Crucial point…
  - Labor demand

$$n^D(\{w(\theta)\}, \{p_i\}, \theta)$$

  - Equilibrium wages…

$$w(\{p_i\}, \{n(\theta)\}, \theta)$$



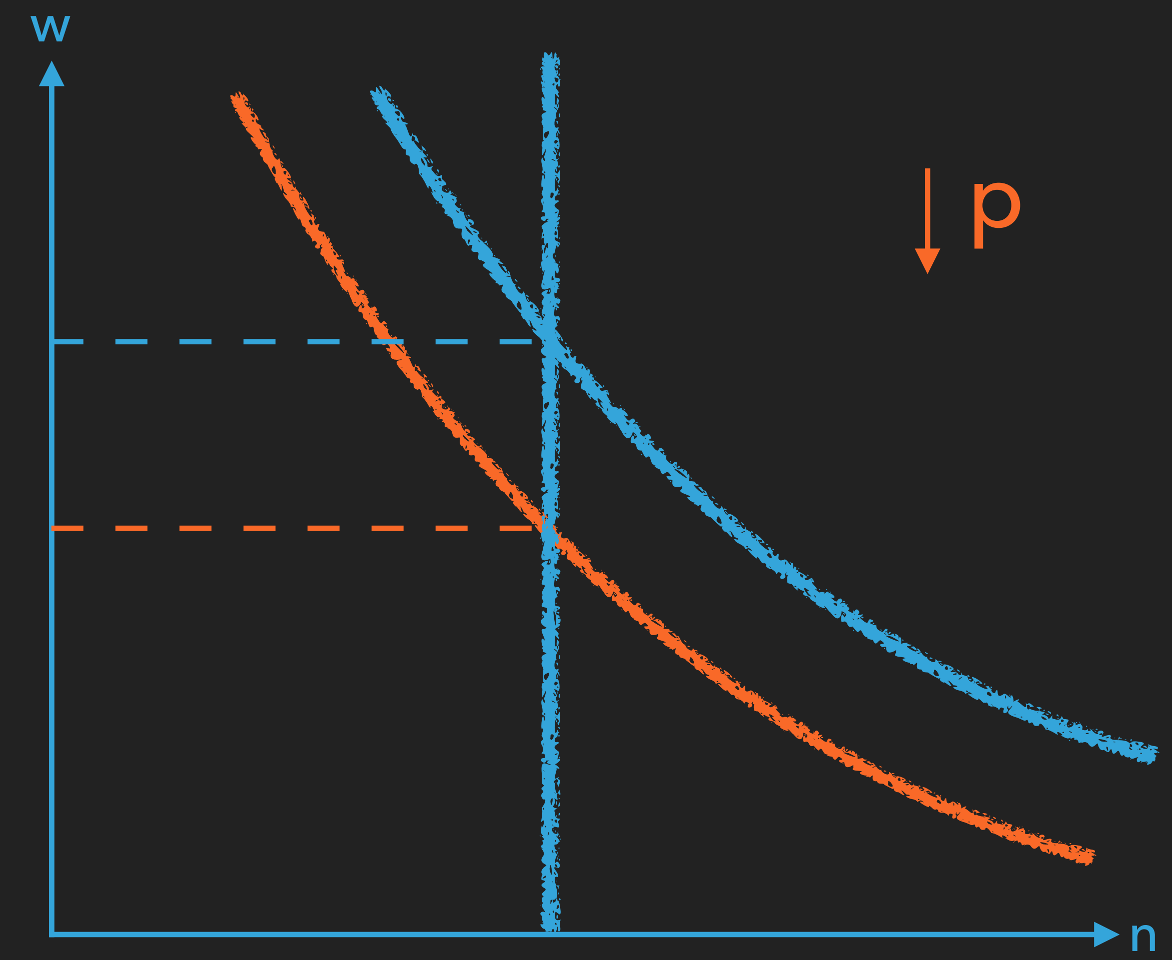
EQUILIBRIUM WAGES

- Crucial point…
  - Labor demand

    $$n^D(\{w(\theta)\},\{p_i\},\theta)$$

  - Equilibrium wages…

    $$w(\{p_i\},\{n(\theta)\},\theta)$$



- t^* can be used to control before tax wages through p

GOVERNMENT

- Welfare Objective

$$W(\bar{U})$$

GOVERNMENT

- Welfare Objective

$$W(\bar{U})$$

only constraint: depends only on distribution of utilities $\bar{U} \equiv \{\bar{U}(z)\}$

GOVERNMENT

- Welfare Objective

$$W(\bar{U})$$

only constraint: depends only on distribution of utilities $\bar{U} \equiv \{\bar{U}(z)\}$

- Government budget constraint implied by Walras' Law

GOVERNMENT

- Welfare Objective

$$W(\bar{U})$$

only constraint: depends only on distribution of utilities $\bar{U} \equiv \{\bar{U}(z)\}$

- Government budget constraint implied by Walras' Law

- Planning Problem: best competitive equilibrium with taxes

WHEN IS TECHNOLOGICAL CHANGE WELCOME?

TECHNOLOGICAL CHANGE

$$W(\phi) = \text{Optimized Welfare}$$

PROPOSITION.

$$dW/d\phi > 0 \quad \Longleftrightarrow \quad \partial G^*/\partial \phi < 0$$

TECHNOLOGICAL CHANGE

$$W(\phi) = \text{Optimized Welfare}$$

Same as First-Best **No Immiserizing Growth!**

PROPOSITION.

$$dW/d\phi > 0 \quad \longleftrightarrow \quad \partial G^*/\partial\phi < 0$$

TECHNOLOGICAL CHANGE

$$W(\phi) = \text{Optimized Welfare}$$

- Envelope...

$$\frac{dW}{d\phi} = -\gamma \frac{\partial G^*}{\partial \phi}$$

Same as First-Best

No Immiserizing Growth!

PROPOSITION.

$$dW/d\phi > 0 \iff \partial G^*/\partial \phi < 0$$

TECHNOLOGICAL CHANGE

$$W(\phi) = \text{Optimized Welfare}$$

- Envelope…

$$\frac{dW}{d\phi} = -\gamma \frac{\partial G^*}{\partial \phi}$$

Same as First-Best

No Immiserizing Growth!

PROPOSITION.

$$dW/d\phi > 0 \quad \Longleftrightarrow \quad \partial G^*/\partial \phi < 0$$

- Extension: even if not optimal …

… Pareto improvement exists (extension of Dixit-Norman)

IMPLICATION: IMPACT OF TRADE SHOCK ONLY DEPENDS ON TOT

- Trade shock

$$\frac{dW}{d\phi} > 0 \iff \sum_i \bar{p}_i'(\phi)(-y_i^*) > 0$$

- TOT determines good vs. bad
- China Shock is good!

IMPLICATION: NO TAXATION OF INNOVATION

- Suppose new tech firms may also choose technology:

$$\{y_i^*, \phi^*\} \in \arg \max_{\{\tilde{y}_i\}, \phi \in \bar{\Phi}} \{\sum p_i^* \tilde{y}_i | G^*(\{\tilde{y}_i\}; \phi) \leq 0\}$$

$$\bar{\Phi} \subset \Phi$$

IMPLICATION: NO TAXATION OF INNOVATION

- Suppose new tech firms may also choose technology:

$$\{y_i^*, \phi^*\} \in \arg \max_{\{\tilde{y}_i\}, \phi \in \bar{\Phi}} \{\sum p_i^* \tilde{y}_i | G^*(\{\tilde{y}_i\}; \phi) \leq 0\}$$

- Government can restrict innovation: $\bar{\Phi} \subset \Phi$

IMPLICATION: NO TAXATION OF INNOVATION

- Suppose new tech firms may also choose technology:

$$\{y_i^*, \phi^*\} \in \arg \max_{\{\tilde{y}_i\}, \phi \in \bar{\Phi}} \{\sum p_i^* \tilde{y}_i | G^*(\{\tilde{y}_i\}; \phi) \leq 0\}$$

- Government can restrict innovation: $\bar{\Phi} \subset \Phi$
- Result: No restriction on innovation!

IMPLICATION: NO TAXATION OF INNOVATION

- Suppose new tech firms may also choose technology:

$$\{y_i^*, \phi^*\} \in \arg \max_{\{\tilde{y}_i\}, \phi \in \bar{\Phi}} \{\sum p_i^* \tilde{y}_i | G^*(\{\tilde{y}_i\}; \phi) \leq 0\}$$

- Government can restrict innovation: $\bar{\Phi} \subset \Phi$
- Result: No restriction on innovation!
- Important…

IMPLICATION: NO TAXATION OF INNOVATION

- Suppose new tech firms may also choose technology:

$$\{y_i^*, \phi^*\} \in \arg \max_{\{\tilde{y}_i\}, \phi \in \bar{\Phi}} \{\sum p_i^* \tilde{y}_i | G^*(\{\tilde{y}_i\}; \phi) \leq 0\}$$

- Government can restrict innovation: $\bar{\Phi} \subset \Phi$
- Result: No restriction on innovation!
- Important…
  - relies on taxes on use of technology…

IMPLICATION: NO TAXATION OF INNOVATION

- Suppose new tech firms may also choose technology:

$$\{y_i^*, \phi^*\} \in \arg \max_{\{\tilde{y}_i\}, \phi \in \bar{\Phi}} \{\sum p_i^* \tilde{y}_i | G^*(\{\tilde{y}_i\}; \phi) \leq 0\}$$

- Government can restrict innovation: $\bar{\Phi} \subset \Phi$
- Result: No restriction on innovation!
- Important…
  - relies on taxes on use of technology…
  - … otherwise: distort innovation! (future work)

HOW SHOULD GOVERNMENT POLICY RESPOND?

2ND WELFARE THEOREM

- **Lump-sum taxes**

$$T(w(\theta)n(\theta);\theta) = T(\theta)$$

- **At the Optimum**
  - Zero taxes on new technology $p = p^*$
  - Production efficiency: Free trade, no robot tax

DIAMOND-MIRRLEES (1971), DIXIT-NORMAN (1985)

- **Linear taxation**

$$T(w(\theta)n(\theta);\theta) = \tau(\theta)w(\theta)n(\theta)$$

DIAMOND-MIRRLEES (1971), DIXIT-NORMAN (1985)

- **Linear taxation**

$$T(w(\theta)n(\theta);\theta) = \tau(\theta)w(\theta)n(\theta)$$

- **At the Optimum**
  - Same taxes on old and new tech: $p = p^*$
  - Production efficiency: Free trade; No tax on robots

DIAMOND-MIRRLEES (1971), DIXIT-NORMAN (1985)

- **Linear taxation**

$$T(w(\theta)n(\theta);\theta) = \tau(\theta)w(\theta)n(\theta)$$

- **At the Optimum**
  - Same taxes on old and new tech: $p = p^*$
  - Production efficiency: Free trade; No tax on robots

Surprising!

Why?

DIAMOND-MIRRLEES (1971), DIXIT-NORMAN (1985)

- **Linear taxation**

$$T(w(\theta)n(\theta);\theta) = \tau(\theta)w(\theta)n(\theta)$$

- **At the Optimum**
  - Same taxes on old and new tech: $p = p^*$
  - Production efficiency: Free trade; No tax on robots

Surprising!
Why?

→ **Key: complete tax system controls after-tax wages**

$$(1-\tau(\theta))w(\theta)$$

THIS PAPER: MORE RESTRICTED TAX INSTRUMENTS

- **Non-linear income taxation**

$$T(w(\theta)n(\theta);\theta) = T(w(\theta)n(\theta))$$

incomplete labor tax

- **Endogenous wages…**

$$w(\{p_i\}, \{n(\theta)\}, \theta)$$

THIS PAPER: MORE RESTRICTED TAX INSTRUMENTS

- **Non-linear income taxation**

$$T(w(\theta)n(\theta);\theta) = T(w(\theta)n(\theta))$$

incomplete labor tax

- **Endogenous wages…**

$$w(\{p_i\}, \{n(\theta)\}, \theta)$$

- Optimality conditions, two ways…
  - first-order conditions
  - variations (Today)

THIS PAPER: MORE RESTRICTED TAX INSTRUMENTS

- **Non-linear income taxation**

$$T(w(\theta)n(\theta);\theta) = T(w(\theta)n(\theta))$$

incomplete labor tax

- **Endogenous wages…**

$$w(\{p_i\}, \{n(\theta)\}, \theta)$$

- Optimality conditions, two ways…
  - first-order conditions
  - variations (Today)
- Two formulas…
  - No change in T
  - No change in $\bar{U} \equiv \{\bar{U}(z)\}$

EFFICIENCY VS REDISTRIBUTION

General variation $\delta t^*, \delta T \to \delta p, \delta w, \delta y^*, \delta n$

$$-\sum_i t_i^* (p_i^* y_i^*) \delta \ln y_i^* - \int \tau(z) \bar{x}(z) \delta \ln \bar{n}(z) \, dz$$

$$= \int [\bar{\lambda}(z) - 1] \bar{x}(z) [(1 - \tau(z)) \, \delta \ln \bar{w}(z) - \frac{\delta T(z)}{\bar{x}(z)} - \sum_i \frac{p_i \bar{c}_i(z)}{\bar{x}(z)} \delta \ln p_i] \, dz,$$

EFFICIENCY VS REDISTRIBUTION

General variation $\delta t^*, \delta T \rightarrow \delta p, \delta w, \delta y^*, \delta n$

$$-\sum_i t_i^*(p_i^* y_i^*)\delta \ln y_i^* - \int \tau(z)\bar{x}(z)\delta \ln \bar{n}(z)\, dz$$

$$= \int [\bar{\lambda}(z) - 1]\bar{x}(z)[(1-\tau(z))\,\delta \ln \bar{w}(z) - \frac{\delta T(z)}{\bar{x}(z)} - \sum_i \frac{p_i \bar{c}_i(z)}{\bar{x}(z)}\delta \ln p_i]\, dz,$$

- Single dimension of heterogeneity z !

EFFICIENCY VS REDISTRIBUTION

General variation $\delta t^*, \delta T \to \delta p, \delta w, \delta y^*, \delta n$

$$-\sum_i t_i^* (p_i^* y_i^*) \delta \ln y_i^* - \int \tau(z) \bar{x}(z) \delta \ln \bar{n}(z)\, dz$$

$$= \int [\bar{\lambda}(z) - 1] \bar{x}(z) [(1 - \tau(z))\, \delta \ln \bar{w}(z) - \frac{\delta T(z)}{\bar{x}(z)} - \sum_i \frac{p_i \bar{c}_i(z)}{\bar{x}(z)} \delta \ln p_i]\, dz,$$

- Single dimension of heterogeneity z !
- Distributional effects… (given welfare weights)
    - wage
    - tax
    - price/inflation

EFFICIENCY VS REDISTRIBUTION

General variation $\delta t^*, \delta T \to \delta p, \delta w, \delta y^*, \delta n$

$$-\sum_i t_i^*(p_i^* y_i^*)\delta \ln y_i^* - \int \tau(z)\bar{x}(z)\delta \ln \bar{n}(z)\, dz$$

$$= \int [\bar{\lambda}(z) - 1]\bar{x}(z)[(1-\tau(z))\,\delta \ln \bar{w}(z) - \frac{\delta T(z)}{\bar{x}(z)} - \sum_i \frac{p_i \bar{c}_i(z)}{\bar{x}(z)}\delta \ln p_i]\, dz,$$

welfare weight

- Single dimension of heterogeneity z !
- Distributional effects… (given welfare weights)
  - wage
  - tax
  - price/inflation

EFFICIENCY VS REDISTRIBUTION

General variation $\delta t^*, \delta T \to \delta p, \delta w, \delta y^*, \delta n$

$$- \sum_i t_i^* (p_i^* y_i^*) \delta \ln y_i^* - \int \tau(z) \bar{x}(z) \delta \ln \bar{n}(z) \, dz$$

$$= \int [\bar{\lambda}(z) - 1] \bar{x}(z) [(1 - \tau(z)) \, \delta \ln \bar{w}(z) - \frac{\delta T(z)}{\bar{x}(z)} - \sum_i \frac{p_i \bar{c}_i(z)}{\bar{x}(z)} \delta \ln p_i] \, dz,$$

welfare weight

- Single dimension of heterogeneity z !
- Distributional effects… (given welfare weights)
  - wage
  - tax
  - price/inflation

EFFICIENCY VS REDISTRIBUTION

General variation $\delta t^*, \delta T \to \delta p, \delta w, \delta y^*, \delta n$

$$- \sum_i t_i^* (p_i^* y_i^*) \delta \ln y_i^* - \int \tau(z) \bar{x}(z) \delta \ln \bar{n}(z)\, dz$$

$$= \int [\bar{\lambda}(z) - 1] \bar{x}(z) [(1 - \tau(z))\, \delta \ln \bar{w}(z) - \frac{\delta T(z)}{\bar{x}(z)} - \sum_i \frac{p_i \bar{c}_i(z)}{\bar{x}(z)} \delta \ln p_i]\, dz,$$

welfare weight

- Single dimension of heterogeneity z !
- Distributional effects… (given welfare weights)
    - wage
    - tax
    - price/inflation

EFFICIENCY VS REDISTRIBUTION

General variation $\delta t^*, \delta T \to \delta p, \delta w, \delta y^*, \delta n$

$$-\sum_i t_i^*(p_i^* y_i^*)\delta \ln y_i^* - \int \tau(z)\bar{x}(z)\delta \ln \bar{n}(z)\, dz$$

$$= \int [\bar{\lambda}(z) - 1]\bar{x}(z)\left[(1-\tau(z))\,\delta \ln \bar{w}(z) - \frac{\delta T(z)}{\bar{x}(z)} - \sum_i \frac{p_i \bar{c}_i(z)}{\bar{x}(z)}\delta \ln p_i\right] dz,$$

welfare weight

- Single dimension of heterogeneity z !
- Distributional effects… (given welfare weights)
  - wage
  - tax
  - price/inflation

EFFICIENCY VS REDISTRIBUTION

General variation $\delta t^*, \delta T \to \delta p, \delta w, \delta y^*, \delta n$

$$-\sum_i t_i^*(p_i^* y_i^*)\delta \ln y_i^* - \int \tau(z)\bar{x}(z)\delta \ln \bar{n}(z)\, dz$$

$$= \int [\bar{\lambda}(z) - 1]\bar{x}(z)\left[(1-\tau(z))\,\delta \ln \bar{w}(z) - \frac{\delta T(z)}{\bar{x}(z)} - \sum_i \frac{p_i \bar{c}_i(z)}{\bar{x}(z)}\delta \ln p_i\right] dz,$$

welfare weight

- Single dimension of heterogeneity z !
- Distributional effects… (given welfare weights)
  - wage
  - tax
  - price/inflation
- Fiscal externalities…
  - linear tax (Harberger triangle)
  - nonlinear income taxation from change in labor

EFFICIENCY VS REDISTRIBUTION

General variation $\delta t^*, \delta T \rightarrow \delta p, \delta w, \delta y^*, \delta n$

$$-\sum_i t_i^*(p_i^* y_i^*)\delta \ln y_i^* - \int \tau(z)\bar{x}(z)\delta \ln \bar{n}(z)\, dz$$

$$= \int [\bar{\lambda}(z) - 1]\bar{x}(z)[(1-\tau(z))\,\delta \ln \bar{w}(z) - \frac{\delta T(z)}{\bar{x}(z)} - \sum_i \frac{p_i \bar{c}_i(z)}{\bar{x}(z)}\delta \ln p_i]\, dz,$$

welfare weight

- Single dimension of heterogeneity z !
- Distributional effects… (given welfare weights)
  - wage
  - tax
  - price/inflation
- Fiscal externalities…
  - linear tax (Harberger triangle)
  - nonlinear income taxation from change in labor

EFFICIENCY VS REDISTRIBUTION

General variation $\delta t^*, \delta T \to \delta p, \delta w, \delta y^*, \delta n$

$$-\sum_i t_i^* (p_i^* y_i^*) \delta \ln y_i^* - \int \tau(z) \bar{x}(z) \delta \ln \bar{n}(z)\, dz$$

$$= \int [\bar{\lambda}(z) - 1] \bar{x}(z) \left[(1 - \tau(z))\, \delta \ln \bar{w}(z) - \frac{\delta T(z)}{\bar{x}(z)} - \sum_i \frac{p_i \bar{c}_i(z)}{\bar{x}(z)} \delta \ln p_i \right] dz,$$

welfare weight

- Single dimension of heterogeneity z !
- Distributional effects… (given welfare weights)
  - wage
  - tax
  - price/inflation
- Fiscal externalities…
  - linear tax (Harberger triangle)
  - nonlinear income taxation from change in labor

FORMULA #1

No Change in T ...

$$t_i^* = \int [1 - \frac{\bar{\lambda}(z)}{\int \bar{\lambda}(v)dv}] \frac{\bar{x}(z)}{p_i^* y_i^*} [(1-\tau(z)) \frac{\delta \ln \bar{w}(z)}{\delta \ln y_i^*}|_{\delta T=0} - \sum_j \frac{p_j \bar{c}_j(z)}{\bar{x}(z)} \frac{\delta \ln p_j}{\delta \ln y_i^*}|_{\delta T=0}] dz$$

$$- \int \tau(z) \frac{\bar{x}(z)}{p_i^* y_i^*} \frac{\delta \ln \bar{n}(z)}{\delta \ln \bar{w}(z)}|_{\delta T=0} \frac{\delta \ln \bar{w}(z)}{\delta \ln y_i^*}|_{\delta T=0} dz$$

FORMULA #1

No Change in T ...

$$t_i^* = \int [1 - \frac{\bar{\lambda}(z)}{\int \bar{\lambda}(v)dv}] \frac{\bar{x}(z)}{p_i^* y_i^*} [(1-\tau(z)) \frac{\delta \ln \bar{w}(z)}{\delta \ln y_i^*}|_{\delta T=0} - \sum_j \frac{p_j \bar{c}_j(z)}{\bar{x}(z)} \frac{\delta \ln p_j}{\delta \ln y_i^*}|_{\delta T=0}] dz$$
$$- \int \tau(z) \frac{\bar{x}(z)}{p_i^* y_i^*} \frac{\delta \ln \bar{n}(z)}{\delta \ln \bar{w}(z)}|_{\delta T=0} \frac{\delta \ln \bar{w}(z)}{\delta \ln y_i^*}|_{\delta T=0} dz$$

- Distributional effects…
  - wage
  - price/inflation
  - tax
- Fiscal Externalities
  - linear tax (Harberger triangle)
  - nonlinear income taxation from change in labor

FORMULA #1

No Change in T ...

$$t_i^* = \int [1 - \frac{\bar{\lambda}(z)}{\int \bar{\lambda}(v)dv}] \frac{\bar{x}(z)}{p_i^* y_i^*} [(1-\tau(z)) \frac{\delta \ln \bar{w}(z)}{\delta \ln y_i^*}|_{\delta T=0} - \sum_j \frac{p_j \bar{c}_j(z)}{\bar{x}(z)} \frac{\delta \ln p_j}{\delta \ln y_i^*}|_{\delta T=0}] dz$$

$$- \int \tau(z) \frac{\bar{x}(z)}{p_i^* y_i^*} \frac{\delta \ln \bar{n}(z)}{\delta \ln \bar{w}(z)}|_{\delta T=0} \frac{\delta \ln \bar{w}(z)}{\delta \ln y_i^*}|_{\delta T=0} dz$$

- Distributional effects…
  - wage
  - price/inflation
  - ~~tax~~
- Fiscal Externalities
  - linear tax (Harberger triangle)
  - nonlinear income taxation from change in labor

FORMULA #1 REDUX

No Change in T ...

$$t_i^* = \int [1 - \frac{\bar{\lambda}(z)}{\int \bar{\lambda}(v)dv}] \frac{\bar{x}(z)}{p_i^* y_i^*} [(1-\tau(z)) \frac{\delta \ln \bar{w}(z)}{\delta \ln y_i^*}|_{\delta T=0} - \sum_j \frac{p_j \bar{c}_j(z)}{\bar{x}(z)} \frac{\delta \ln p_j}{\delta \ln y_i^*}|_{\delta T=0}]dz$$

$$- \int \tau(z) \frac{\bar{x}(z)}{p_i^* y_i^*} \frac{\delta \ln \bar{n}(z)}{\delta \ln \bar{w}(z)}|_{\delta T=0} \frac{\delta \ln \bar{w}(z)}{\delta \ln y_i^*}|_{\delta T=0} dz$$

- Strict generalization of Grossman-Helpman formula
- Here…
  - other instrument for redistribution (T)
  - elastic labor supply
  - general preferences and technology

FORMULA #1 REDUX

No Change in T ...

$$t_i^* = \int [1 - \frac{\bar{\lambda}(z)}{\int \bar{\lambda}(v)dv}] \frac{\bar{x}(z)}{p_i^* y_i^*} [\cancel{(1-\tau(z))} \frac{\delta \ln \bar{w}(z)}{\delta \ln y_i^*}|_{\delta T=0} - \sum_j \frac{p_j \bar{c}_j(z)}{\bar{x}(z)} \frac{\delta \ln p_j}{\delta \ln y_i^*}|_{\delta T=0}] dz$$

$$- \int \tau(z) \frac{\bar{x}(z)}{p_i^* y_i^*} \frac{\delta \ln \bar{n}(z)}{\delta \ln \bar{w}(z)}|_{\delta T=0} \frac{\delta \ln \bar{w}(z)}{\delta \ln y_i^*}|_{\delta T=0} dz$$

- Strict generalization of Grossman-Helpman formula
- Here…
  - other instrument for redistribution (T)
  - elastic labor supply
  - general preferences and technology

FORMULA #1 REDUX

No Change in T ...

$$t_i^* = \int [1 - \frac{\bar\lambda(z)}{\int \bar\lambda(v)dv}] \frac{\bar x(z)}{p_i^* y_i^*} [(1 - \tau(z)) \frac{\delta \ln \bar w(z)}{\delta \ln y_i^*} |_{\delta T=0} - \sum_j \frac{p_j \bar c_j(z)}{\bar x(z)} \frac{\delta \ln p_j}{\delta \ln y_i^*} |_{\delta T=0}] dz$$

$$- \int \tau(z) \frac{\bar x(z)}{p_i^* y_i^*} \frac{\delta \ln \bar n(z)}{\delta \ln \bar w(z)} |_{\delta T=0} \frac{\delta \ln \bar w(z)}{\delta \ln y_i^*} |_{\delta T=0} dz$$

- Strict generalization of Grossman-Helpman formula
- Here…
    - other instrument for redistribution (T)
    - elastic labor supply
    - general preferences and technology

FORMULA #1 REDUX

No Change in T ...

$$t_i^* = \int [1 - \frac{\bar{\lambda}(z)}{\int \bar{\lambda}(v)dv}] \frac{\bar{x}(z)}{p_i^* y_i^*} [(1 - \tau(z)) \frac{\delta \ln \bar{w}(z)}{\delta \ln y_i^*} |_{\delta T=0} - \sum_j \frac{p_j \bar{c}_j(z)}{\bar{x}(z)} \frac{\delta \ln p_j}{\delta \ln y_i^*} |_{\delta T=0}] dz$$

$$- \int \tau(z) \frac{\bar{x}(z)}{p_i^* y_i^*} \frac{\delta \ln \bar{n}(z)}{\delta \ln \bar{w}(z)} |_{\delta T=0} \frac{\delta \ln \bar{w}(z)}{\delta \ln y_i^*} |_{\delta T=0} dz$$

- Strict generalization of Grossman-Helpman formula
- Here…
  - other instrument for redistribution (T)
  - elastic labor supply
  - general preferences and technology

FORMULA #1 REDUX

No Change in T …

$$t_i^* = \int [1 - \frac{\bar{\lambda}(z)}{\int \bar{\lambda}(v)dv}] \frac{\bar{x}(z)}{p_i^* y_i^*} [(1 - \tau(z)) \frac{\delta \ln \bar{w}(z)}{\delta \ln y_i^*}|_{\delta T=0} - \sum_j \frac{p_j \bar{c}_j(z)}{\bar{x}(z)} \frac{\delta \ln p_j}{\delta \ln y_i^*}|_{\delta T=0}] dz$$

$$- \int \tau(z) \frac{\bar{x}(z)}{p_i^* y_i^*} \frac{\delta \ln \bar{n}(z)}{\delta \ln \bar{w}(z)}|_{\delta T=0} \frac{\delta \ln \bar{w}(z)}{\delta \ln y_i^*}|_{\delta T=0} dz$$

- Strict generalization of Grossman-Helpman formula
- Here…
  - other instrument for redistribution (T)
  - elastic labor supply
  - general preferences and technology

FORMULA #1 REDUX

No Change in T ...

$$p_i - p_i^* = \left(\frac{\bar{\lambda}(i)}{\int \bar{\lambda}(v) dv} - 1 \right) \times \left(- \frac{d\bar{x}(i)}{dy_i^*} \right)$$

- Trade policy as redistribution
- Protection in sector i depends on:
  - Pareto weight on sector i's workers (relative to others)
  - marginal impact of imports decrease on their earnings
- Political-economy considerations determine Pareto weights

FORMULA #2

No Change in $\bar{U}$ …

$\omega(z) = w'(z)/w(z)$

$$t_i^* = \int \tau(z) \frac{\bar{x}(z)}{p^* y_i^*} \, \frac{\varepsilon_H(z)}{\varepsilon_M(z)+1} \, \frac{\delta \ln \omega(z)}{\delta \ln y_i^*} |_{\delta \bar{U}=0} \, dz$$

FORMULA #2

No Change in $\bar{U}$ ... $\omega(z) = w'(z)/w(z)$

$$t_i^* = \int \tau(z) \frac{\bar{x}(z)}{p^* y_i^*} \frac{\varepsilon_H(z)}{\varepsilon_M(z)+1} \frac{\delta \ln \omega(z)}{\delta \ln y_i^*}\Big|_{\delta \bar{U}=0} dz$$

- Distributional effects…
  - ~~wage~~
  - ~~price/inflation~~
  - ~~tax~~
- Fiscal Externalities
  - linear tax (Harberger triangle)
  - nonlinear income taxation from change in labor

FORMULA #2

No Change in $\bar{U}$ …

$\omega(z) = w'(z)/w(z)$

$$t_i^* = \int \tau(z) \frac{\bar{x}(z)}{p^* y_i^*} \frac{\varepsilon_H(z)}{\varepsilon_M(z)+1} \frac{\delta \ln \omega(z)}{\delta \ln y_i^*}|_{\delta \bar{U}=0}\, dz$$

- Distributional effects…
  - ~~wage~~
  - ~~price/inflation~~
  - ~~tax~~
- Fiscal Externalities
  - linear tax (Harberger triangle)
  - nonlinear income taxation from change in labor

FORMULA #2

No Change in $\bar{U}$ …

$$t_i^* = \int \tau(z) \frac{\bar{x}(z)}{p^* y_i^*} \frac{\varepsilon_H(z)}{\varepsilon_M(z) + 1} \frac{\delta \ln \omega(z)}{\delta \ln y_i^*} |_{\delta \bar{U} = 0} \, dz$$

FORMULA #2

No Change in $\bar{U}$ …

$$t_i^* = \int \tau(z) \frac{\bar{x}(z)}{p^* y_i^*} \frac{\varepsilon_H(z)}{\varepsilon_M(z)+1} \frac{\delta \ln \omega(z)}{\delta \ln y_i^*}\Big|_{\delta \bar{U}=0} dz$$

- Sufficient Statistic…
  - ~~welfare weight~~
  - taxes, earnings
  - elasticities
  - marginal impact on wage
  - details of production function structure irrelevant!

FORMULA #2

No Change in $\bar{U}$ ...

$$t_i^* = \int \tau(z) \frac{\bar{x}(z)}{p^* y_i^*} \frac{\varepsilon_H(z)}{\varepsilon_M(z)+1} \frac{\delta \ln \omega(z)}{\delta \ln y_i^*}|_{\delta \bar{U}=0} \, dz$$

- Sufficient Statistic...
  - ~~welfare weight~~ **WHY??????**
  - taxes, earnings
  - elasticities
  - marginal impact on wage
  - details of production function structure irrelevant!

FORMULA #2

No Change in $\bar{U}$ ...

$$t_i^* = \int \tau(z) \frac{\bar{x}(z)}{p^* y_i^*} \frac{\varepsilon_H(z)}{\varepsilon_M(z) + 1} \frac{\delta \ln \omega(z)}{\delta \ln y_i^*} |_{\delta \bar{U} = 0} \, dz$$

- Sufficient Statistic…
  - ~~welfare weight~~
  - taxes, earnings
  - elasticities
  - marginal impact on wage
  - details of production function structure irrelevant!

WHY??????

No change in welfare!

FORMULA #2

No Change in $\bar{U}$ ...

$$t_i^* = \int \tau(z) \frac{\bar{x}(z)}{p^* y_i^*} \frac{\varepsilon_H(z)}{\varepsilon_M(z)+1} \frac{\delta \ln \omega(z)}{\delta \ln y_i^*}|_{\delta \bar{U}=0}\, dz$$

- Sufficient Statistic…
  - ~~welfare weight~~
  - taxes, earnings
  - elasticities
  - marginal impact on wage
  - details of production function structure irrelevant!

WHY??????

No change in welfare!

detects Pareto improvements

FORMULA #2

No Change in $\bar{U}$ ...

$$t_i^* = \int \tau(z) \frac{\bar{x}(z)}{p^* y_i^*} \frac{\varepsilon_H(z)}{\varepsilon_M(z)+1} \frac{\delta \ln \omega(z)}{\delta \ln y_i^*}_{\delta \bar{U}=0} dz$$

- Sufficient Statistic…
  - ~~welfare weight~~
  - taxes, earnings
  - elasticities
  - marginal impact on wage
  - details of production function structure irrelevant!

WHY??????

No change in welfare!

detects Pareto improvements

SUMMARY

$$t_i^* = \int \tau(z) \frac{\bar{x}(z)}{p^* y_i^*} \frac{\varepsilon_H(z)}{\varepsilon_M(z) + 1} \frac{\delta \ln \omega(z)}{\delta \ln y_i^*} |_{\delta \bar{U} = 0} \, dz$$

SUMMARY

$$t_i^* = \int \tau(z) \frac{\bar{x}(z)}{p^* y_i^*} \, \frac{\varepsilon_H(z)}{\varepsilon_M(z)+1} \, \frac{\delta \ln \omega(z)}{\delta \ln y_i^*}|_{\delta \bar{U}=0} \, dz$$

- Formula…

SUMMARY

$$t_i^* = \int \tau(z) \frac{\bar{x}(z)}{p^* y_i^*} \frac{\varepsilon_H(z)}{\varepsilon_M(z)+1} \frac{\delta \ln \omega(z)}{\delta \ln y_i^*}\Big|_{\delta \bar{U}=0} \, dz$$

- Formula…
  - Sufficient statistic: wage impacts quantile regressions

SUMMARY

$$t_i^* = \int \tau(z) \frac{\bar{x}(z)}{p^* y_i^*} \, \frac{\varepsilon_H(z)}{\varepsilon_M(z)+1} \, \frac{\delta \ln \omega(z)}{\delta \ln y_i^*}|_{\delta \bar{U}=0} \, dz$$

- Formula…
  - Sufficient statistic: wage impacts quantile regressions
  - No welfare weights needed

SUMMARY

$$t_i^* = \int \tau(z) \frac{\bar{x}(z)}{p^* y_i^*} \frac{\varepsilon_H(z)}{\varepsilon_M(z)+1} \frac{\delta \ln \omega(z)}{\delta \ln y_i^*}|_{\delta \bar{U}=0}\, dz$$

- Formula…
  - Sufficient statistic: wage impacts quantile regressions
  - No welfare weights needed
  - Pigouvian “fiscal externality” intuition

SUMMARY

$$t_i^* = \int \tau(z) \frac{\bar{x}(z)}{p^* y_i^*} \frac{\varepsilon_H(z)}{\varepsilon_M(z)+1} \frac{\delta \ln \omega(z)}{\delta \ln y_i^*} |_{\delta \bar{U}=0} \, dz$$

- Formula…
  - Sufficient statistic: wage impacts quantile regressions
  - No welfare weights needed
  - Pigouvian “fiscal externality” intuition
  - Predistribution vs. Redistribution

FORMULA #2 REDUX

$$t_i^* = \int \tau(z) \frac{\bar{x}(z)}{p_i^* y_i^*} \frac{\varepsilon_H(z)}{\varepsilon_M(z)+1} \frac{\delta \ln \omega(z)}{\delta \ln y_i^*}\Big|_{\delta \bar{U}=0} dz + O(\bar{\varepsilon}^2)$$

alternative:
any feasible
variation

FORMULA #2 REDUX

$$t_i^* = \int \tau(z) \frac{\bar{x}(z)}{p_i^* y_i^*} \frac{\varepsilon_H(z)}{\varepsilon_M(z) + 1} \frac{\delta \ln \omega(z)}{\delta \ln y_i^*} \Big|_{\delta \bar{U}=0} \, dz + O(\bar{\varepsilon}^2)$$

alternative:
any feasible
variation

- Two effects...
  - direct effect on wages from more Robots
  - indirect effect from labor supply responses

FORMULA #2 REDUX

$$t_i^* = \int \tau(z) \frac{\bar{x}(z)}{p_i^* y_i^*} \frac{\varepsilon_H(z)}{\varepsilon_M(z)+1} \frac{\delta \ln \omega(z)}{\delta \ln y_i^*}\Big|_{\delta \bar{U}=0} dz + O(\bar{\varepsilon}^2)$$

X alternative: any feasible variation

- Two effects…
  - direct effect on wages from more Robots
  - indirect effect from labor supply responses

FORMULA #2 REDUX

$$t_i^* = \int \tau(z) \frac{\bar{x}(z)}{p_i^* y_i^*} \frac{\varepsilon_H(z)}{\varepsilon_M(z)+1} \frac{\delta \ln \omega(z)}{\delta \ln y_i^*}\Big|_{\delta \bar{U}=0} dz + O(\bar{\varepsilon}^2)$$

alternative:
any feasible
variation

- Two effects…
  - direct effect on wages from more Robots
  - indirect effect from labor supply responses
- Intuition
  - indirect effect depends on elasticity…
  - … contribution is second order

APPLICATION TO ROBOTS AND TRADE

PUTTING THE FORMULA TO WORK

- **Compute taxes using formula…**
  - Use reduced-form evidence as input
  - No further structure
- **Comparative static on technology change…**
  - How do taxes vary as machines get cheaper?
  - More structure

QUANTITATIVE EXERCISE

- Formula #2 Redux…

$$t_m^* \simeq \int \tau(z) \frac{\bar{x}(z)}{p_m^* y_m^*} \frac{\varepsilon_H(z)}{\varepsilon_M(z)+1} \frac{\delta \ln \omega(z)}{\delta \ln y_m^*} \, dz$$

QUANTITATIVE EXERCISE

- Formula #2 Redux…

$$t_m^* \simeq \int \tau(z) \frac{\bar{x}(z)}{p_m^* y_m^*} \frac{\varepsilon_H(z)}{\varepsilon_M(z)+1} \frac{\delta \ln \omega(z)}{\delta \ln y_m^*} \, dz$$

Guner et

QUANTITATIVE EXERCISE

- Formula #2 Redux…

$$t_m^* \simeq \int \tau(z) \frac{\bar{x}(z)}{p_m^* y_m^*} \frac{\varepsilon_H(z)}{\varepsilon_M(z)+1} \frac{\delta \ln \omega(z)}{\delta \ln y_m^*} \, dz$$

Guner et al

Chetty Survey
~0.1 to 0.5

QUANTITATIVE EXERCISE

- Formula #2 Redux…

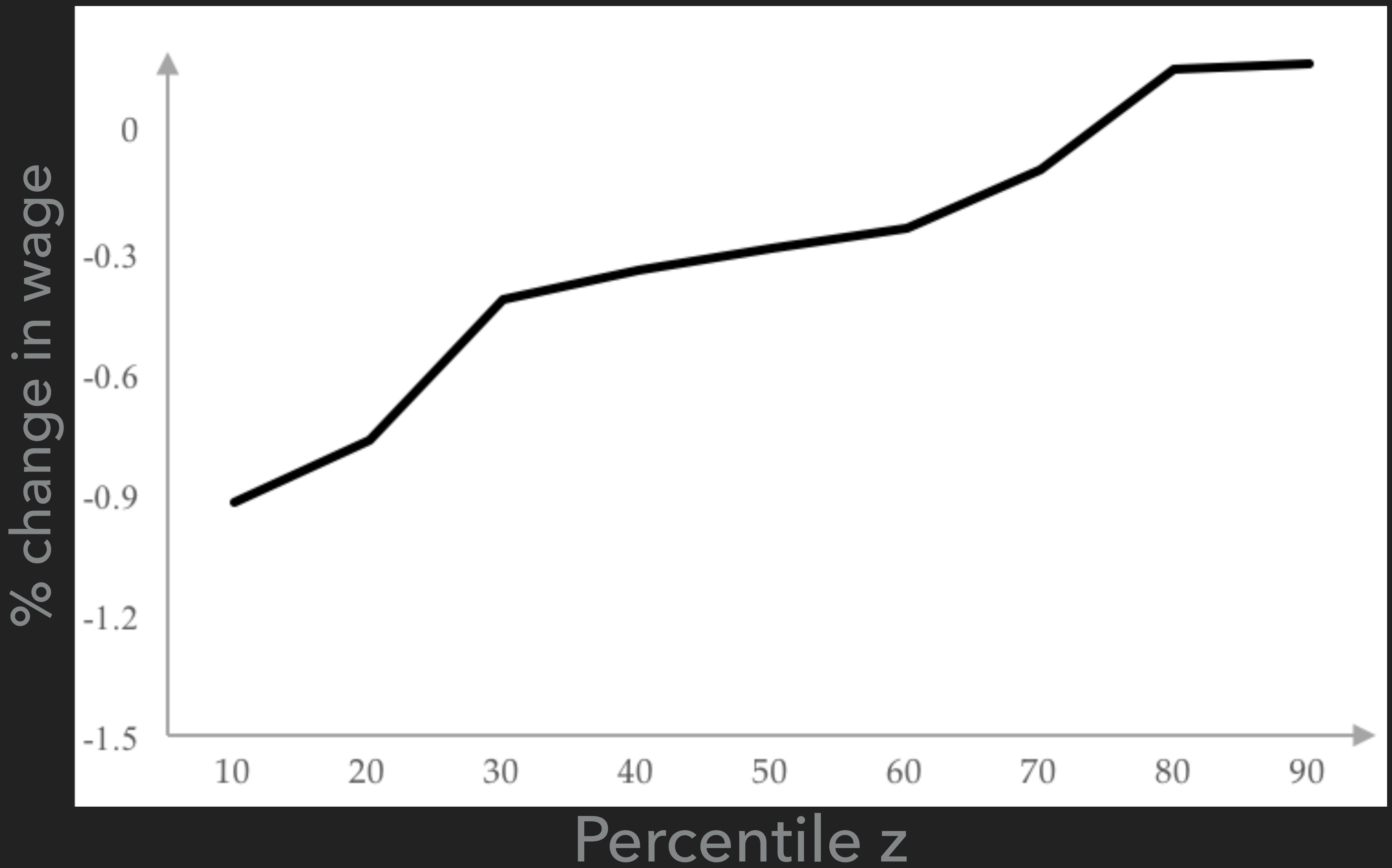
$$t_m^* \simeq \int \tau(z) \frac{\bar{x}(z)}{p_m^* y_m^*} \frac{\varepsilon_H(z)}{\varepsilon_M(z)+1} \frac{\delta \ln \omega(z)}{\delta \ln y_m^*} dz$$

Guner et

Chetty Survey
~0.1 to 0.5

Quantile
IV-Regression
for Wages

WAGE EFFECTS: ROBOTS



Acemoglu-Restrepo (2016)

OPTIMAL TAX ON ROBOTS

$$t_m^* \simeq \int \tau(z) \frac{\bar{x}(z)}{p_m^* y_m^*} \frac{\varepsilon_H(z)}{\varepsilon_M(z)+1} \frac{\delta \ln \omega(z)}{\delta \ln y_m^*} dz$$

Graetz-Michaels

Acemoglu-Restrepo

$$\frac{\delta \ln \omega(z)}{\delta \ln y_m^*} \simeq 0.5\% = 0.005$$

$$\int \frac{\bar{w}(z)\bar{n}(z)}{p_m^* y_m^*} dz \simeq 250$$

OPTIMAL TAX ON ROBOTS

$$t_m^* \simeq \int \tau(z) \frac{\bar{x}(z)}{p_m^* y_m^*} \frac{\varepsilon_H(z)}{\varepsilon_M(z)+1} \frac{\delta \ln \omega(z)}{\delta \ln y_m^*} dz$$

Graetz-Michaels

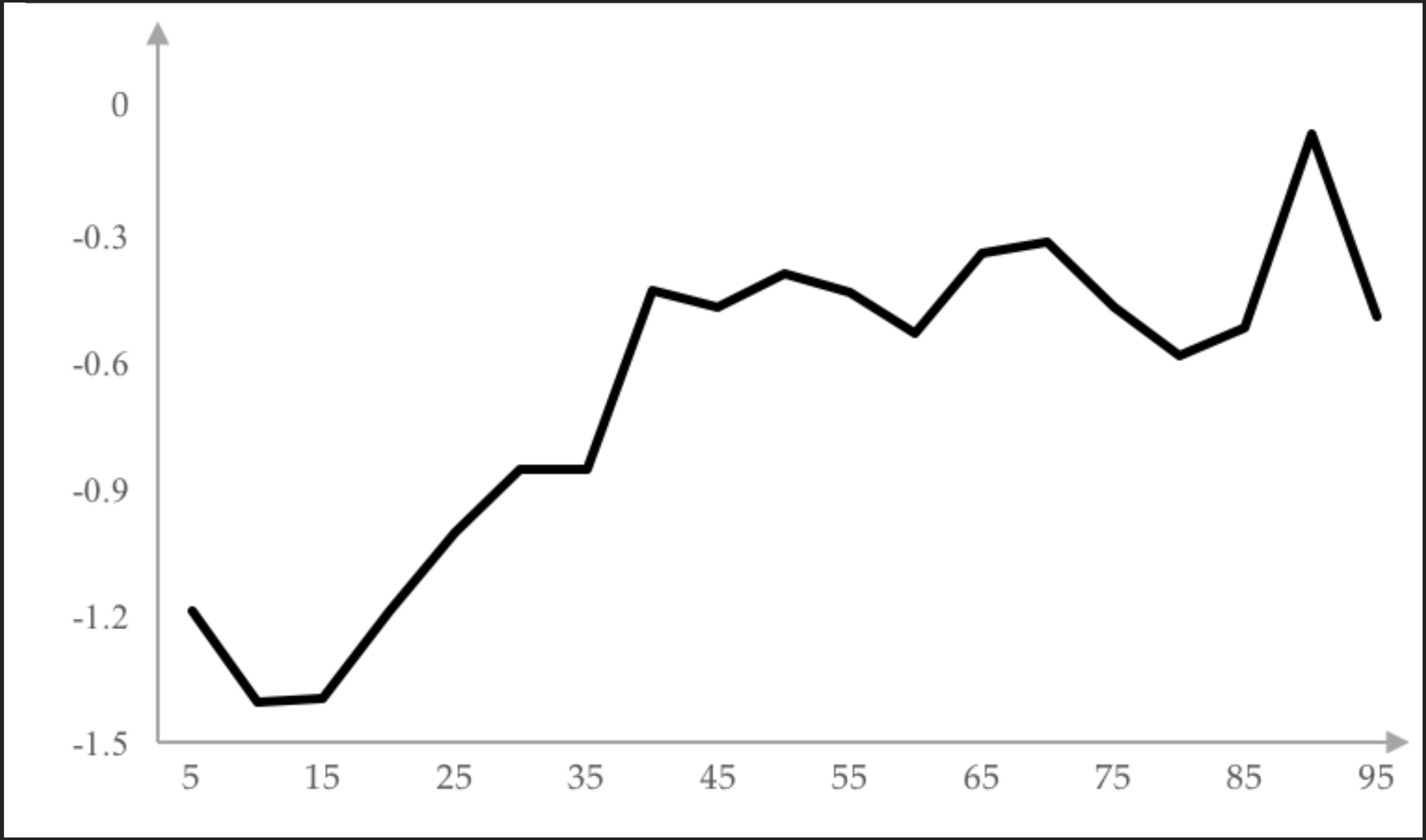
Acemoglu-Restrepo

$$\frac{\delta \ln \omega(z)}{\delta \ln y_m^*} \simeq 0.5\% = 0.005$$

$$\int \frac{\bar{w}(z)\bar{n}(z)}{p_m^* y_m^*} dz \simeq 250$$

$$\longrightarrow \quad t_m^* \in [1\%, 4\%]$$

WAGE EFFECTS: TRADE



% change in wage

Percentile z

Chetverikov, Larsen, and Palmer (2016)

OPTIMAL TAX ON TRADE

$$t_m^* \simeq \int \tau(z) \frac{\bar{x}(z)}{p_m^* y_m^*} \frac{\varepsilon_H(z)}{\varepsilon_M(z)+1} \frac{\delta \ln \omega(z)}{\delta \ln y_m^*} dz$$

Autor-Dorn-Hanson

Chetverikov-Larsen-Palmer

$$\frac{\delta \ln \omega(z)}{\delta \ln y_m^*} \simeq 0.5\% = 0.005$$

$$\int \frac{\bar{w}(z)\bar{n}(z)}{p_m^* y_m^*} dz \simeq 30$$

OPTIMAL TAX ON TRADE

$$t_m^* \simeq \int \tau(z) \frac{\bar{x}(z)}{p_m^* y_m^*} \frac{\varepsilon_H(z)}{\varepsilon_M(z)+1} \frac{\delta \ln \omega(z)}{\delta \ln y_m^*} dz$$

Autor-Dorn-Hanson

Chetverikov-Larsen-Palmer

$$\frac{\delta \ln \omega(z)}{\delta \ln y_m^*} \simeq 0.5\% = 0.005$$

$$\int \frac{\bar{w}(z)\bar{n}(z)}{p_m^* y_m^*} dz \simeq 30$$

$$\longrightarrow \quad t_m^* \in [0.03\%, 0.11\%]$$

COMPARATIVE STATIC

A TWO-GOOD ECONOMY

- Households

$$U = c - h(n)$$

- New tech firms use final good to produce machines

$$y_m^* = \phi y_f^*$$

- Old tech firms use machines + labor to produce final good

$$y_f = \int g(y_m(\theta), n(\theta); \theta) dF(\theta)$$

$$w(p_m, \{n(\theta)\}; \theta)$$

A TWO-GOOD ECONOMY

- Households

$$U = c - h(n)$$

- New tech firms use final good to produce machines

$$y_m^* = \phi y_f^*$$

- Old tech firms use machines + labor to produce final good

$$y_f = \int g(y_m(\theta), n(\theta); \theta) dF(\theta)$$

separability: simplifying assumption

$$w(p_m, \{n(\theta)\}; \theta)$$

A TWO-GOOD ECONOMY

- Households

$$U = c - h(n)$$

- New tech firms use final good to produce machines

$$y_m^* = \phi y_f^*$$

- Old tech firms use machines + labor to produce final good

$$y_f = \int g(y_m(\theta), n(\theta); \theta) dF(\theta)$$

separability: simplifying assumption

$$w(p_m, \{n(\theta)\}; \theta)$$

→ well-known "Stiglitz" effects

(Scheuer-Rotschild, Ales-Kurnaz-Sleet)

A TWO-GOOD ECONOMY

- Households

$$U = c - h(n)$$

- New tech firms use final good to produce machines

$$y_m^* = \phi y_f^*$$

- Old tech firms use machines + labor to produce final good

$$y_f = \int g(y_m(\theta), n(\theta); \theta) dF(\theta)$$

separability: simplifying assumption

$$w(p_m, \{n(\theta)\}; \theta)$$

our focus

well-known "Stiglitz" effects

(Scheuer-Rotschild, Ales-Kurnaz-Sleet)

COMPARATIVE STATICS WITH PARAMETRIC RESTRICTIONS

- Rawlsian preferences

$$\Lambda(\theta) = 1 \text{ for all } \theta$$

- Iso-elastic labor supply

$$h(n) = \frac{n^{1+1/\epsilon}}{1+1/\epsilon}$$

- Cobb-Douglas production functions

$$g(y_m(\theta), n(\theta); \theta) = \exp(\alpha(\theta)) \cdot (\frac{y_m(\theta)}{\beta(\theta)})^{\beta(\theta)} (\frac{n(\theta)}{1-\beta(\theta)})^{1-\beta(\theta)}$$

- With $\alpha(\theta), \beta(\theta)$ such that Pareto distribution of wages

$$w(p_m; \theta) = (1-\theta)^{-1/\gamma(p_m)}$$

CHEAPER ROBOTS, LESS LUDDISM

- Pareto efficient tax:

$$\frac{t_m^*}{1+t_m^*} = \frac{\frac{\epsilon}{\epsilon+1}\frac{d\ln\omega}{d\ln y_m^*}\tau^*}{1-\frac{\epsilon}{\epsilon+1}\frac{d\ln\omega}{d\ln y_m^*}\tau^*}\frac{\int w(\theta)n(\theta)dF(\theta)}{p_m y_m^*}$$

PROPOSITION.

Optimal tax decreases with robot-makers' productivity.

CHEAPER ROBOTS, LESS LUDDISM

- Pareto efficient tax:

$$\frac{t_m^*}{1+t_m^*} = \frac{\frac{\epsilon}{\epsilon+1}\frac{d\ln\omega}{d\ln y_m^*}\tau^*}{1-\frac{\epsilon}{\epsilon+1}\frac{d\ln\omega}{d\ln y_m^*}\tau^*}\frac{\int w(\theta)n(\theta)dF(\theta)}{p_m y_m^*}$$

PROPOSITION.
Optimal tax decreases with robot-makers' productivity.

- Intuition:
  - Negative fiscal externality caused by more robots

CHEAPER ROBOTS, LESS LUDDISM

- Pareto efficient tax:

$$\frac{t_m^*}{1+t_m^*} = \frac{\frac{\epsilon}{\epsilon+1}\frac{d\ln\omega}{d\ln y_m^*}\tau^*}{1-\frac{\epsilon}{\epsilon+1}\frac{d\ln\omega}{d\ln y_m^*}\tau^*}\frac{\int w(\theta)n(\theta)dF(\theta)}{p_m y_m^*}$$

PROPOSITION.
Optimal tax decreases with robot-makers' productivity.

- Intuition:
  - Negative fiscal externality caused by more robots
  - But, at the margin, externality decreases with # robots…

CHEAPER ROBOTS, LESS LUDDISM

- Pareto efficient tax:

$$\frac{t_m^*}{1+t_m^*} = \frac{\frac{\epsilon}{\epsilon+1}\frac{d\ln\omega}{d\ln y_m^*}\tau^*}{1-\frac{\epsilon}{\epsilon+1}\frac{d\ln\omega}{d\ln y_m^*}\tau^*}\frac{\int w(\theta)n(\theta)dF(\theta)}{p_m y_m^*}$$

PROPOSITION.
Optimal tax decreases with robot-makers' productivity.

- Intuition:
  - Negative fiscal externality caused by more robots
  - But, at the margin, externality decreases with # robots…

Pigou → Lower tax

CHEAPER ~~ROBOTS~~, LESS ~~LUDDISM~~

IMPORTS PROTECTIONISM

- Pareto efficient tax:

$$\frac{t_m^*}{1+t_m^*} = \frac{\frac{\epsilon}{\epsilon+1}\frac{d\ln\omega}{d\ln y_m^*}\tau^*}{1-\frac{\epsilon}{\epsilon+1}\frac{d\ln\omega}{d\ln y_m^*}\tau^*}\frac{\int w(\theta)n(\theta)dF(\theta)}{p_m y_m^*}$$

PROPOSITION.
Optimal tax decreases with ~~robot-makers'~~ foreign productivity.

- Intuition:
  - Negative fiscal externality caused by more robots
  - But, at the margin, externality decreases with # robots…

Pigou → Lower tax

CONCLUDING REMARKS

SUMMARY

SUMMARY

1. When is technological change welcome?
    - Like in a first best world (despite not being first best)
        - No rationale for taxing innovation
        - Impact of trade shock only depends on TOT

SUMMARY

1. When is technological change welcome?
   - Like in a first best world (despite not being first best)
     - No rationale for taxing innovation
     - Impact of trade shock only depends on TOT
2. How should government policy respond?
   - Formulas as functions of shares & elasticities
   - As process of automation and globalization deepens, more inequality may best be met with lower Luddism

SUMMARY

1. When is technological change welcome?
   - Like in a first best world (despite not being first best)
     - No rationale for taxing innovation
     - Impact of trade shock only depends on TOT
2. How should government policy respond?
   - Formulas as functions of shares & elasticities
   - As process of automation and globalization deepens, more inequality may best be met with lower Luddism

More: Natural resources? Immigration? Innovation?

NEXT?...


©'16 PLASTICS NEWS
TRADE DEALS
These guys seem a bit too enthusiastic...
FOR CHINA TARIFFS
TPP= LOST U.S. JOBS
TPP

APPENDIX

EXTENSION

PROP 2. No distortion between consumers and New tech

- Intuition…
  - motive for distortion is to manipulate wages…
  - … households do not demand labor and their consumption does not affect wages
- Implication…
  - no trade protection that leads to higher prices for consumers
  - no taxes on Robots for household uses

CORRELATIONS AND BOUNDS

- What goods do we tax more?

COROL 1. **Optimal distortion between old and new technology**

$$(p^* - p)' \cdot \int (\Lambda(\theta) - F(\theta))(1 - \tau(\theta))x(\theta)(\nabla_p \omega(\theta))dF(\theta) \geq 0$$

- What can we say if we do not know Pareto weights?

COROL 2. **Taxes on both old and new technology**

$$D_{p_i} y \cdot (tp) \leq \int (\mathbf{1}_{\Theta_i^+}(\theta) - F(\theta))(1 - \tau(\theta))x(\theta)\omega_{p_i}(\theta)d\theta,$$

$$D_{p_i} y \cdot (tp) \geq \int (\mathbf{1}_{\Theta_i^-}(\theta) - F(\theta))(1 - \tau(\theta))x(\theta)\omega_{p_i}(\theta)d\theta$$