# Welfare and Output with Income Effects and Taste Shocks

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[1] The conclusions and analysis are our own, calculated in part on data from Nielsen Consumer LLC and provided through the NielsenIQ Datasets at the Kilts Center for Marketing Data Center at The University of Chicago Booth School of Business. NielsenIQ is not responsible for, had no role in, and was not involved in analyzing and preparing the results reported herein.

# Motivation

- How does welfare respond to changes in choice sets?

  *"How much endowment at $t_0$ to make consumer indifferent between choice set in $t_0$ and $t_1$?"*

- If preferences stable and homothetic: can express welfare as chained (or Divisia) index.

$$\Delta \text{Welfare} = \log \frac{spending_{t_1}}{spending_{t_0}} - \int_{t_0}^{t_1} \sum_i \frac{p_{i,t} c_{i,t}}{spend_t} \, d \log p_{i,t}$$

- Foundation for aggregation procedures to calculate aggregate quantities and prices.

- What if demand is unstable and/or non-homothetic.

# What We Do

- Consider preferences that are unstable and/or non-homothetic.

- Characterize welfare change and chained objects in PE and GE in terms of suff. stats.

  - Chaining treats all expenditure-switching equally (due to prices, income, taste shocks), but welfare does not.
  - PE/GE distinction matters when pref. unstable or non-homoth.
  - Generalize Hulten's Theorem.

- Quantitative applications for long-run growth and fluctuations.

  1. Welfare-relevant Baumol's cost disease.
  2. Firm-level shocks and industry-level outcomes.
  3. PE vs. GE during Covid-19 recession
     Path-dependence/Index-drift of RGDP and TFP.

# Selected Literature

- Biases of real consumption/GDP:
  Fisher & Shell (1968), Hausman (1981), Feenstra (1994), Basu et al. (2012), Aghion et al. (2019), Syverson (2017), Jones & Klenow (2016).

- Index numbers with taste shocks or non-homotheticity:
  Caves, Christensen, Diewert (1982), Deaton & Muellbauer (1980), Feenstra & Reinsdorf (2007), Redding & Weinstein (2020), Atkin et al. (2020).

- Growth accounting and disaggregated macro:
  Solow (1951), Domar (1961), Hulten (1978), Long & Plosser (1983), Gabaix (2011), Acemoglu et al. (2012), Baqaee & Farhi (2019).

- Structural Transformation
  Baumol (1961), Kongsamut, Rebelo, Xie (2001), Buera & Kaboski (2009), Herrendorf et al. (2013), Boppart (2014), Comin et al. (2020), Alder et al. (2019).

# Agenda

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Microeconomic Problem

Macroeconomic Problem

Applications

Extensions

Conclusion

# Set up

- Preference relations $\{\succeq_x\}$ over vector of consumption goods $c$.
  ($x$ is e.g. age, fads, advertising, state of nature, no choices/preferences over $x$)
- Represent preferences by $u(c; x)$ with indirect utility $v(p, \mathrm{I}; x)$.
- Consider change from $(p_{t_0}, \mathrm{I}_{t_0}, x_{t_0})$ to $(p_{t_1}, \mathrm{I}_{t_1}, x_{t_1})$.
- Consider how welfare changes.
- Consider how (chained) real consumption changes.
- Compare the difference.

# Micro Welfare and Real Consumption

## Definition

Change in real consumption is

$$\Delta \log Y = \Delta \log \mathrm{I} - \int_{t_0}^{t_1} \sum_i \frac{p_{i,t} c_{i,t}}{\mathrm{I}_t} d \log p_{i,t}.$$

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Income needed under $p_{t_0}$ to make $\succeq_{x_{t_1}}$ indifferent to $(p_{t_1}, \mathrm{I}_{t_1})$.

$$v(p_{t_0}, e^{\mathbf{EV^m}} I_{t_0}; x_{t_1}) = v(p_{t_1}, I_{t_1}; x_{t_1})$$

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- EV because it is a money-metric representation of u (CV is not).
- Uses only ordinal (not cardinal) information on preferences.
- $t_1$ preferences because more relevant than $t_0$ preferences.
- For welfare, quality $\neq$ taste.

# Change in real consumption versus welfare

Define $b(p, u, x)$ to be budget share given $p$, $u$, and $x$.

# Change in real consumption versus welfare

Define $b(p, u, x)$ to be budget share given $p$, $u$, and $x$.

## Lemma

$$\Delta \log Y = \Delta \log \mathrm{I} - \int_{t_0}^{t_1} \sum_i b_i(p_t, u_t, x_t) d \log p_{i,t}.$$

$$EV^m = \Delta \log \mathrm{I} - \int_{t_0}^{t_1} \sum_i b_i(p_t, u_{t_1}, x_{t_1}) d \log p_{i,t}.$$

*where $b(p, u, x)$ denotes budget share at $(p, u, x)$*

If preferences stable and homothetic, $b_i(p_t, u_t, x_t) = b_i(p_t, u_{t_1}, x_{t_1})$.

For welfare, substitution effect $\neq$ income effect & taste shocks.

derivation

# Key Intuition for Consumption vs. Welfare

$$\Delta \log Y = \Delta \log \mathrm{I} - \int_{t_0}^{t_1} \sum_i b_i(p_t, u_t, x_t) d \log p_{i,t}.$$

$$EV^m = \Delta \log \mathrm{I} - \int_{t_0}^{t_1} \sum_i b_i(p_t, u_{t_1}, x_{t_1}) d \log p_{i,t}.$$

- Consider change in welfare comparing 1950 to 2014.
- Spend more on healthcare in 2014 due to aging and income.
- Chained index uses 1950 demand to weight prices in 1950.
- Welfare-relevant uses 2014 demand to weight prices in 1950.
- Welfare uses $x_{t_1}$ since households are older and $u_{t_1}$ since we are giving them income in 1950 to make them indifferent to 2014.

# Example of Implementation

- Consider e.g non-homothetic CES with taste shocks where

$$e(p_t, u_t, x_t) = \left( \sum_i \omega_i x_{it} p_{it}^{1-\theta} u_t^{\xi_i} \right)^{\frac{1}{1-\theta}} u_t.$$

- To measure welfare, integrate $b(p, u_{t_1}, x_{t_1}) d \log p$:

$$EV^m = \Delta \log I + \log \left( \sum_i b_{it_1} \left( \frac{p_{it_0}}{p_{it_1}} \right)^{1-\theta} \right)^{\frac{1}{1-\theta}}.$$

- If we know elasticity of substitution, we don't need to know income elasticities or taste shocks (or even separate them).

cross-sectional implementation a la Jaravel & Lashkari (2022) | cardinal utility measure

# Second-order Approx.

Real consumption is

$$\Delta \log Y = \Delta \log I_t - \int_{t_0}^{t_1} \sum_{i \in N} b_{it} \frac{d \log p_{it}}{dt} dt.$$

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$$\Delta \log Y \approx \underbrace{\Delta \log I - \mathbb{E}_b(\Delta \log p)}_{\text{first-order}} - \underbrace{\frac{1}{2} Cov_b(\Delta \log b, \Delta \log p)}_{\text{second-order}},$$

If spending rises for goods that got more expensive, then $\Delta \log Y$ falls.

# Consumption vs. Welfare: Second-order Approx.

Consider Taylor expansion in $t_1$ around $t_0$:

$$\Delta \log Y \approx \underbrace{\Delta \log I - \mathbb{E}_b [\Delta \log p]}_{\text{First-order}}$$

,

$$EV^m \approx \Delta \log I - \mathbb{E}_b [\Delta \log p]$$

.

To a first-order, welfare and real consumption are the same.

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$$- \frac{1}{2} \underbrace{Cov_b (\Delta \log x, \Delta \log p)}_{\substack{\text{expenditure-switching} \\ \text{due to taste shock}}} \quad ,$$

$$EV^m \approx \Delta \log I - \mathbb{E}_b [\Delta \log p] - \frac{1}{2}(1-\theta_0)\, Var_b (\Delta \log p)$$

$$-1 \times Cov_b (\Delta \log x, \Delta \log p) \quad .$$

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No bias if covariances are zero. quality change

# Agenda

# Set up

- Perfectly competitive neoclassical economy, representative agent
- $F$ primary factors, $N$ goods

$$y_i = A_i G_i \left( \{m_{ij}\}_{j \in N}, \{l_{ij}\}_{j \in F} \right)$$

- Macro indirect utility of representative agent is

$$V(A, L; x) = \max\{u(c; x) : c \text{ is feasible}\}.$$

- Consider changes in technologies from $(A_{t_0}, L_{t_0})$ to $(A_{t_1}, L_{t_1})$ and preferences from $x_{t_0}$ to $x_{t_1}$.
- These imply some $(p_{t_0}, I_{t_0})$ and $(p_{t_1}, I_{t_1})$.

# Micro Welfare Poor Measure of Technology Change

- Suppose households age from $t_0$ to $t_1$ but technology unchanged.

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- But technology has not changed:
  *A society of old people indifferent between tech in $t_0$ and $t_1$.*
- Macro welfare takes into account that prices respond to demand.

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# Macro Welfare

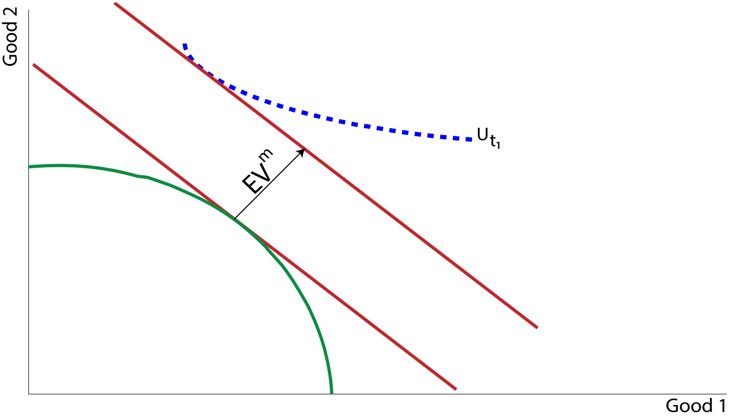
To quantify welfare effect of changes in technologies, we ask:

*Factors needed in $t_0$ to make $\succeq_{x_{t_1}}$ indifferent to $t_1$ technologies.*

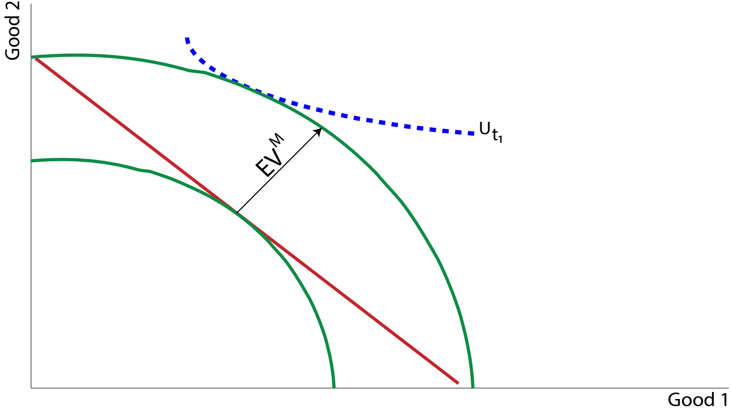
$$V(A_{t_0}, e^{\mathbf{EV^M}} L_{t_0}; x_{t_1}) = V(A_{t_1}, L_{t_1}; x_{t_1}).$$

- When preferences are stable + homothetic, or PPF is linear:
  - macro welfare is the same as micro welfare.

# Graphical Representation – Micro $EV^m$



# Graphical Representation – Macro $EV^M$



# Real GDP and Welfare

- Let $\lambda_i(A, u, x)$ be sales shares, $\frac{p_i y_i}{GDP}$, with demand $b(p, u, x)$.

## Proposition

*Change in real GDP and welfare in response to $(\Delta x, \Delta A)$ is*

$$\Delta \log Y = \int_{t_0}^{t_1} \sum_i \lambda_i(A_t, u_t, x_t) d \log A_{i,t},$$

$$EV^M = \int_{t_0}^{t_1} \sum_i \lambda_i(A_t, u_{t_1}, x_{t_1}) d \log A_{i,t}.$$

# Simple Examples

- Consider non-homothetic CES consumer

- One sector economy with no intermediates and one factor:

$$EV^M - \Delta \log Y \approx \frac{1}{2} \underbrace{Cov_b\left(\Delta \log x, \Delta \log A\right)}_{\text{gap due to taste shocks}} + \frac{1}{2} \underbrace{Cov_b\left(\varepsilon, \Delta \log A\right) \mathbb{E}_b[\Delta \log A]}_{\text{gap due to income effects}}.$$

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- With roundabout (larger changes in sales shares due to taste):

$$EV^M - \Delta \log Y \approx \frac{1}{2} \frac{1}{(1-\Omega_{ii})} \left[ Cov_b(\Delta \log x, \Delta \log A) + Cov_b\left(\varepsilon, \Delta \log A\right) \mathbb{E}_b[\Delta \log A] \right],$$

where $\Omega_{ii}$ is Cobb-Douglas intermediate input share.

# Simple Example with Nonlinear PPF

- One sector with Cobb-Douglas decreasing returns to scale:

$$EV^M - \Delta \log Y \approx \frac{1}{2} \frac{Cov_b(\Delta \log x, \Delta \log A)}{1 + (\theta_0 - 1)(1 - \gamma)}.$$

Sales shares respond more to taste shocks if complements and DRS.

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  Sales shares respond more to taste shocks if complements and DRS.

- With only taste shocks, Micro and Macro welfare are different.

$$EV^m \approx -\frac{1}{2} \frac{(1-\gamma)}{(1 + (\theta_0 - 1)(1 - \gamma))} Var_b(\Delta \log x) \neq 0 = EV^M.$$

# Implementation: notation

- Let
$$\Omega_{ij} = \frac{p_j m_{ij}}{p_i y_i},$$
be input-output matrix.

- Let
$$\Psi = (I - \Omega)^{-1} = I + \Omega + \Omega^2 + \dots$$
be Leontief inverse.

- Denote Hicksian sales share
$$\lambda^{ev}(A) \equiv \lambda(A, u_{t_1}, x_{t_1}).$$

# Implementation

- Consider non-homothetic CES consumer + CES producers.
- Observed sales:

$$d\lambda_{it} = \underbrace{\sum_{j\in\{0\}+N+F} \lambda_{jt}(\theta_j - 1)Cov_{\Omega_{(j,:),t}}\left(-d\log p_t, \Psi_{(:,i),t}\right)}_{\text{substitution effect}}$$

$$+ \underbrace{Cov_{\Omega_{(0,:),t}}\left(d\log x_t, \Psi_{(:,i),t}\right)}_{\text{taste shocks}} + \underbrace{Cov_{\Omega_{(0,:),t}}(\varepsilon_t, \Psi_{(:,i),t})\left(\sum_{kt\in N} \lambda_k d\log A_{kt}\right)}_{\text{income effect}}.$$

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- Welfare-relevant sales (starting at $t_1$ and going back to $t_0$)

$$d\lambda_{it}^{ev} = \sum_{j\in\{0\}+N+F} \lambda_{jt}^{ev}(\theta_j - 1)Cov_{\Omega^{ev}_{(j,:),t}}\left(-d\log p_t^{ev}, \Psi^{ev}_{(:,i),t}\right).$$

- Real GDP uses $\lambda_i$, welfare uses $\lambda_i^{ev}$.

prices

# Agenda

# Implications for Long-Run Growth

As economies grow, low-productivity-growth sectors expand.
(Baumol's cost disease)

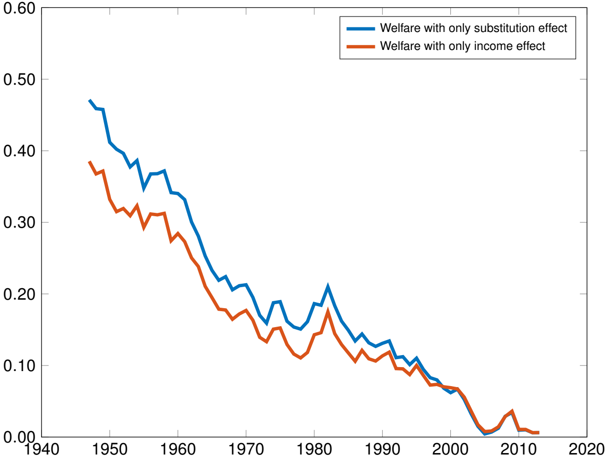
## Corollary

*If structural transformation is due only to:*

- *substitution effects, then welfare-TFP uses chained sales shares.*
- *income effects or taste shocks, then welfare-TFP uses terminal sales shares.*

# Growth in welfare TFP between *t* and 2014 in the US

61 private-sector industries, gross-output TFP as in Jorgenson et al. (2005) and Carvalho and Gabaix (2013)




- Settling dispute about income v. substitution effects has important welfare implications.

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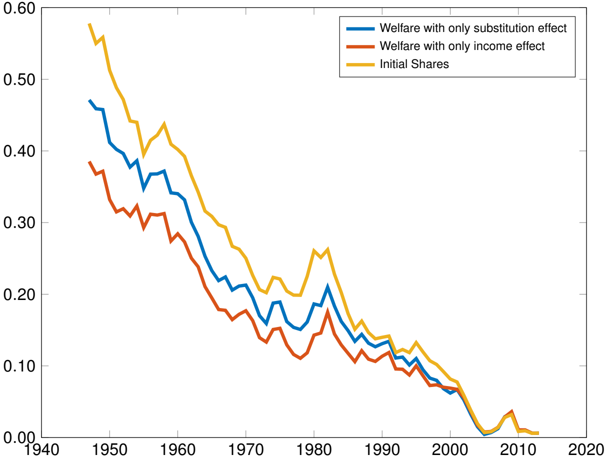


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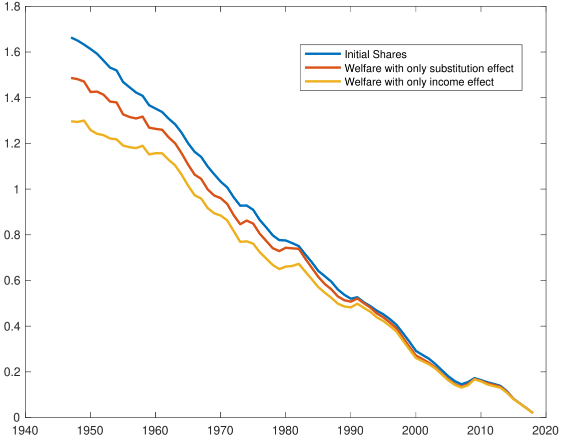
# Quantitative Experiment

- $\theta_0$ elasticity of sub. between primary/manufacturing/services.
- $\theta_1$ elasticity of sub. within primary/manufacturing/services.
- $\theta_2$ elasticity of sub. between materials.
- $\theta_4$ elasticity of sub. between VA-materials.

Table: US from 1948 to 2015.

| $(\theta_0, \theta_1, \theta_2, \theta_3)$ | (1,1,1,1) | (0.5,1,1,1) | (1,0.5,1,1) | (1,1,0.5,1) | (1,1,1,0.5) |
|---|---|---|---|---|---|
| Welfare TFP | 46% | 46% | 54% | 48% | 55% |
| Measured TFP | 60% | 60% | 60% | 60% | 60% |
| Constant-share TFP | 78% | 78% | 78% | 78% | 78% |

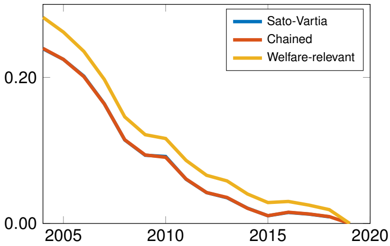
# US welfare between *t* and 2019 using consumption data



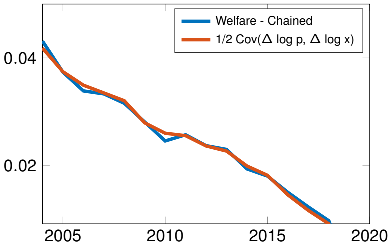
# Implications for Short-Run Growth

- Biases can also matter at more disaggregated level.
- The more we disaggregate, the more shares vary.
  (increasing scope for bias).
- Within-industry firm-level shocks can cause industry-level price/quantity to be mismeasured.
- Use Nielsen UPC-level data 2004-2019 and CES with taste shocks and elasticity of substitution 4.5 to quantify.

# UPC-level inflation rate for continuing varieties




(a) Inflation rates




(b) Bias

- Welfare-relevant inflation is higher than chained.

  Price and demand shocks are positively correlated.

- Gap widens as we extend horizon due to persistence.

- Covariance formula works well.

# Implications for Business Cycles

- Consider application to Covid-19 recession: mixture of supply and demand shifters.
- 66 sector model with input-output linkages and complementarities in production, as in Baqaee-Farhi (2021).
- Labor market segmented by sector.
- Supply shocks: labor supplied to match reductions in employment from Q1 to Q2 of 2020.
- Demand shocks: taste shifters to match changes in PCE expenditures from Q1 to Q2 of 2020.

# Macro vs. Micro welfare

Welfare Feb to May, 2020 using structural model

| Elasticities | Medium compl. | Cobb-Douglas |
|---|---|---|
| Micro Covid preferences | -12.3% | -10.9% |
| Macro Covid preferences | -9.4% | -9.0% |
| Chained real consumption | -10.6% | -9.8% |

- Micro welfare losses larger than RGDP because prices rise for goods with increasing demand.
- Macro losses smaller than micro since part of price rises were due to changes in demand.
- Chaining under-measures micro losses, and over-measures macro losses

# RGDP as Measure of Production

- What are implications for comparing RGDP to model predictions?
- Consider two different time-paths of shocks:
  - Supply shocks first, then demand shifters.
  - Demand shifters first, then supply shocks.

$\Delta RGDP$ Q1 to Q2, 2020 using structural model.

| Elasticities | Medium compl. | Cobb-Douglas |
|---|---|---|
| Supply then demand | -12.5% | -10.8% |
| Demand then supply | -9.4% | -9.0% |

- RGDP falls by more if supply shocks first, because supply and demand shocks positively correlated.
- If recovery not mirror image of downturn, RGDP off by up to 6%.

# Agenda

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Macroeconomic Problem

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# Extension to Heterogeneous Agents

- Homogeneous agent assumption simplifies exposition, but Baqaee & Burstein (2021) generalizes:

  "*What is the minimum change in endowments in $t_0$ so that it is possible to make every consumer indifferent between $t_0$ and $t_1$?*"

- With this definition, all macro and micro results readily generalize.

# Extensions to Extensive Margin Adjustments

The change in equivalent variation at $t_1$ tastes is given by

$$EV^m = \log \frac{I_{t_1}}{I_{t_0}} - \log \frac{P_{t_1}}{P_{t_0}}, \tag{1}$$

where

$$\frac{P_{t_1}}{P_{t_0}} = \left( \frac{b_{t_1}^c \left(\frac{P_{t_1}^c}{P_{t_0}^c}\right)^{\theta_0 - 1} + \left(1 - b_{t_1}^c\right)\left(\frac{P_{t_1}^n}{P_{t_0}^n}\right)^{\theta_0 - 1}}{1 - b_{t_0}^{x_{t_1}}} \right)^{\frac{1}{\theta_0 - 1}}. \tag{2}$$

- $b_{t_1}^c$ is the share on continuing goods in $t_1$,
- $P_{t_1}^c / P_{t_0}^c$ and $P_{t_1}^n / P_{t_0}^n$ is change in CES index for continuing and new
- $b_{t_0}^{x_{t_1}}$ is share on exiting goods under $t_1$ tastes and $p_{t_0}$ prices.

# Steady-state comparisons in dynamic model

- Intertemporal preferences

$$\mathscr{U}_t = \sum_{s=t}^{\infty} \beta^{s-t} u(C_s), \qquad \sum_i \omega_{i0} x_{it} \left( \frac{c_{is}}{C_s^{\xi_i}} \right)^{\frac{\theta_0 - 1}{\theta_0}} = 1$$

- Goods: $y_{is} = A_{is} G_i \left( \{m_{ijs}\}_{j \in N}, H(l_{is}, k_{is}) \right)$
- Investment: $I_s = A_{Is} I \left( \{m_{Ijs}\}_{j \in N}, H(l_{Is}, k_{Is}) \right)$.
- Capital accumulation $K_{s+1} = (1-\delta)(K_s + I_s)$

## Proposition

*Consider two dynamic economies, denoted $t_0$ and $t_1$, that are in steady-state. The change in macro welfare is given by*

$$EV^M = \log \left( \frac{\sum_i p_{it_1} c_{it_1}}{\sum_i p_{it_0} c_{it_0}} \right) + \log \left( \sum_i b_{it_1} \left( \frac{p_{it_0}}{p_{it_1}} \right)^{1-\theta_0} \right)^{\frac{1}{1-\theta_0}}.$$

# Other Extensions

- Distorted economies.
- Beyond CES.

# Conclusion

- Toolbox for welfare computation. How to modify Divisia/Hulten for taste shocks and non homoth.
- Chaining doesn't correctly account for expenditure-switching caused by taste shocks or income effects.
- In these cases, distinct macro and micro notions of welfare.
- Characterize both and show gap with chained quantity significant when demand shifters covary with supply shifters.

# Changes in Prices

$$d\log p_{it} = \underbrace{-\sum_{j\in\{0\}+N+F} \Psi_{ijt}\, d\log A_{jt}}_{\text{upstream TFP changes}} + \underbrace{\sum_{f\in F} \Psi_{ift}\, d\log \lambda_{ft}}_{\text{upstream factor price changes}} .$$

and

$$d\log p^{ev}_{it} = -\sum_{j\in\{0\}+N+F} \Psi^{ev}_{ijt}\, d\log A_{jt} + \sum_{f\in F} \Psi^{ev}_{ift}\, d\log \lambda^{ev}_{ft}.$$

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# With Quality Change

Change in real consumption

$$\Delta \log Y \approx \Delta \log I - \mathbb{E}_b[\Delta \log \tilde{p}] - \frac{1}{2}(1-\theta_0) Var_b(d\log \tilde{p}) + \frac{1}{2}(1-\theta_0) Cov_b(d\log q, d\log \tilde{p}) - \frac{1}{2} Cov_b(d\log x, d\log \tilde{p}),$$

Change in welfare

$$EV^m \approx \Delta \log I - \mathbb{E}_b[\Delta \log \tilde{p} - \Delta \log q] - \frac{1}{2}(1-\theta_0) Var_b(\Delta \log \tilde{p}) - \frac{1}{2}(1-\theta_0) Var_b(\Delta \log q) + (1-\theta_0) Cov_b(\Delta \log \tilde{p}, \Delta \log q) - Cov_b(\Delta \log x, \Delta \log p),$$

Hence,

$$EV^m - \Delta \log Y \approx \underbrace{\mathbb{E}_b[\Delta \log q]}_{\text{average quality}} + \frac{1}{2}\underbrace{(\theta_0 - 1) Var_b(\Delta \log q)}_{\text{dispersion in quality}} + \frac{1}{2}\underbrace{(1-\theta_0) Cov_b(\Delta \log \tilde{p}, \Delta \log q)}_{\text{covariance of price and quality}} - \frac{1}{2}\underbrace{Cov_b(\Delta \log x, \Delta \log \tilde{p})}_{\text{covariance of taste and price}} + \underbrace{Cov_b(\Delta \log x, \Delta \log q)}_{\text{covariance of taste and quality}}.$$

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# Micro Welfare

## Lemma

$$EV^m = \Delta \log \mathrm{I} - \int_{t_0}^{t_1} \sum_i b_i(p_t, u_{t_1}, x_{t_1}) d \log p_{i,t}.$$

$$\begin{aligned} EV^m &= \log \frac{e(p_{t_0}, v(p_{t_1}, \mathrm{I}_{t_1}; x_{t_1}); x_{t_1})}{e(p_{t_0}, v(p_{t_0}, \mathrm{I}_{t_0}; x_{t_1}); x_{t_1})} = \log \frac{\mathrm{I}_{t_1}}{\mathrm{I}_{t_0}} \times \frac{e(p_{t_0}, u_{t_1}; x_{t_1})}{e(p_{t_1}, u_{t_1}; x_{t_1})} \\ &= \Delta \log \mathrm{I} - \int_{t_0}^{t_1} \sum_i \frac{\partial \log e(p, v(p_{t_1}, \mathrm{I}_{t_1}; x_{t_1}); x_{t_1})}{\partial \log p_i} d \log p_i \\ &= \Delta \log \mathrm{I} - \int_{t_0}^{t_1} \sum_i b_i(p, u_{t_1}, x_{t_1}) \frac{d \log p_i}{dt} dt, \end{aligned}$$

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# Cross-Sectional Implementation

- Jaravel & Lashkari (2022) setting.
- Cross-section facing common prices with same stable $\succeq$.
- Observe $p(t)$ and budget shares $B(I,t)$ at $t \in [t_0, T]$.

## Corollary of Lemma 1

*$EV^m(p(t_0), I(t_0), p(t), I) \equiv \log u(I,t)$ solves following integral equation*

$$\log u(I,t) = \log \frac{I}{I(t_0)} - \int_{t_0}^{t} \sum_i B_i(u^{-1}(u(I,t),s),s) \frac{d \log p_i(s)}{ds} ds$$

*with boundary condition $u(I,t_0) = I$.*

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# Second-order Approximation

- Real GDP:

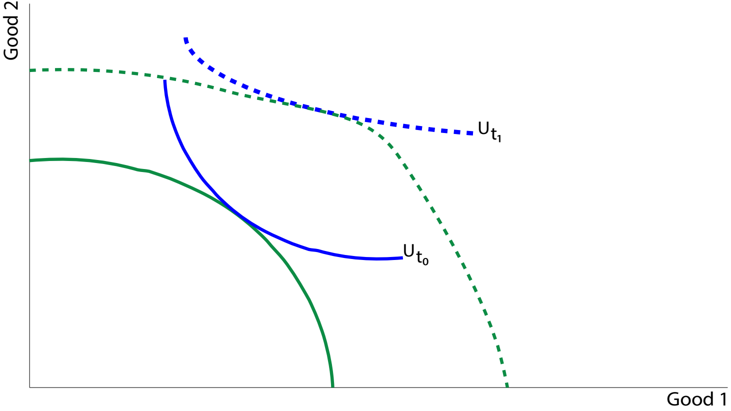
$$\Delta \log Y \approx \sum_i \lambda_i \Delta \log A_i + \frac{1}{2} \underbrace{\sum_i \Delta \lambda_i \Delta \log A_i}_{\text{expenditure switching}} .$$

- Welfare:

$$EV^M \approx \lambda' \Delta \log A + \frac{1}{2} \sum_i \Delta \lambda_i \Delta \log A_i$$
$$+ \frac{1}{2} \sum_i \left[ \Delta \log x' \frac{\partial \lambda_i}{\partial \log x} + \Delta \log A' \frac{\partial u}{\partial \log A} \frac{\partial \lambda_i}{\partial \log u} \right] \Delta \log A_i.$$

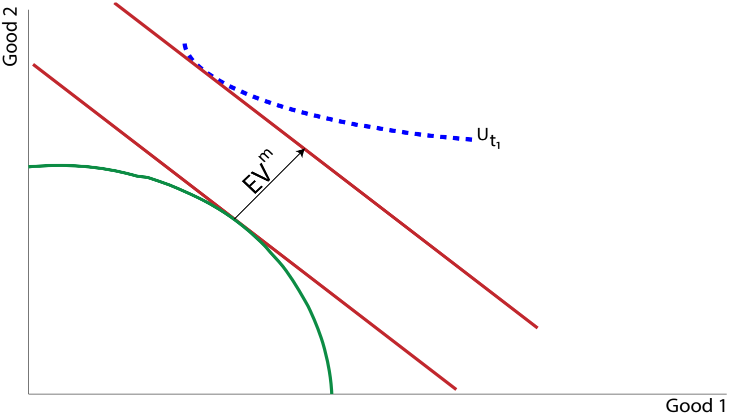
- Changes due to income effects and taste shocks are undercounted.

# Graphical Representation

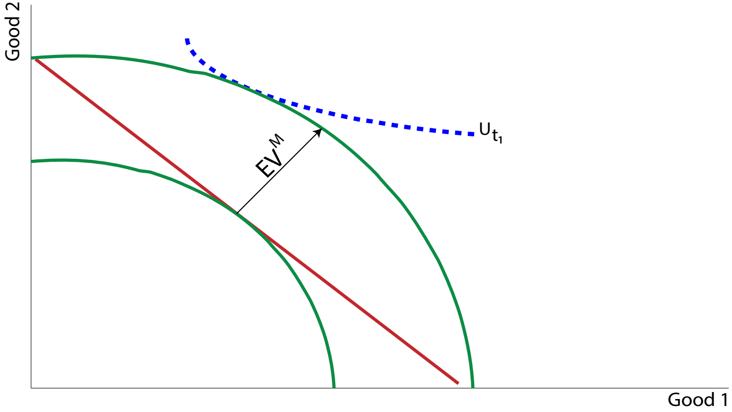



- Objective is to compare value of initial and final technology.

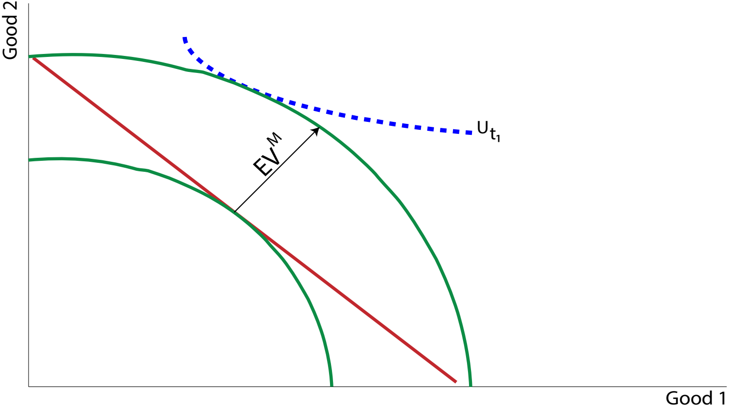
# Graphical Representation – Micro $EV^m$



# Graphical Representation – Macro $EV^M$



# Graphical Representation – Macro $EV^M$




- $EV^M = EV^m$ if PPF is linear or preferences homothetic $+$ stable.

# Cardinal Utility Measure

- Consider e.g non-homothetic CES with taste shocks where

$$e(p_t, u_t, x_t) = \left( \sum_i \omega_i x_{it} p_{it}^{1-\theta} u_t^{\xi_i} \right)^{\frac{1}{1-\theta}} u_t = \tilde{P}_t u_t.$$

$(\Delta u, \Delta \tilde{P})$ not good (quantity, price) measure if non-homo./unstable since it is cardinal.

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