Productivity and the Welfare of Nations

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Questions

- Can we construct intertemporal national welfare measures from observable aggregate data?
- Can we use the answer to make welfare comparisons across countries?
- Do we need to make assumptions about technology and firm behavior to answer these questions?
- What do the data show about welfare across countries and over time?
Questions

- Can we construct intertemporal national welfare measures from observable aggregate data? Yes

- Can we use the answer to make welfare comparisons across countries? Yes

- Do we need to make assumptions about technology and firm behavior to answer these questions? No

- What do the data show about welfare across countries and over time? Let’s see!
Selection of Previous Literature

- Flow welfare measures that improve on GDP
  Nordhaus and Tobin (1973), Jones and Klenow (2010)

- Intertemporal welfare measures

- Welfare in open economies
  Kohli (2004), Kehoe and Ruhl (2008), Arkolakis et al. (2011)

- Public policy and cost-benefit analysis
  Little and Mirrlees (1969); Stiglitz, Sen and Fitoussi (2009)
Maximization problem

- Utility function
  \[ V_t \equiv E_t \sum_{s=0}^\infty \beta^s U(C_{t+s}, \bar{L} - L_{t+s}) \]

- Budget constraint
  \[ P_t^L K_t + B_t = (1 - \delta) P_t^L K_{t-1} + (1 + i_t) B_{t-1} + P_t^L L_t N_t + P_t^K K_t + \Pi_t - P_t^C C_t N_t \]
Optimality conditions

\[ U_{c_t} - \lambda_t p_t^C = 0 \]

\[ U_{L_t} + \lambda_t p_t^L = 0 \]

\[-\lambda_t + \beta E_t \frac{(1 - \delta) + p_{t+1}^K}{(1 + g)(1 + n)} \lambda_{t+1} = 0 \]

\[-\lambda_t + \beta \frac{1}{(1 + g)(1 + n)} E_t (1 + r_{t+1}) \lambda_{t+1} = 0 \]
Approximation around SS

- Log-linearizing and using the FOC we get (an Envelope Theorem result):

\[ v_t = v + E_t \sum_{s=0}^{\infty} \beta^s \lambda \left[ p^L L \hat{p}^L_{t+s} + \frac{p^K k}{(1+g)(1+n)} \hat{p}^K_{t+s} - p^C c \hat{p}^c_{t+s} + \pi \hat{\pi}_{t+s} \right. \\
\left. \quad + \frac{rb}{(1+g)(1+n)} \hat{r}_{t+s} \right] + \lambda \frac{1}{\beta} k \hat{k}_{t-1} + \lambda \frac{(1+r)}{(1+g)(1+n)} b \hat{b}_{t-1} \]

- Welfare depends on the *dual* productivity residual (and other exogenous or predetermined variables)

- Using the log-linearized budget constraint and the FOCs for capital and bonds:

\[ \frac{v_t - v}{\lambda p^Y y} = E_t \sum_{s=0}^{\infty} \beta^s \left[ s_c \hat{c}_{t+s} + s_i \hat{i}_{t+s} - s_L \hat{L}_{t+s} - s_K \hat{k}_{t+s-1} \right] + \frac{1}{\beta} k \frac{k}{p^Y y} \hat{k}_{t-1} \]

- Budget constraint (national income identity) shows that the *dual* equals the *primal* productivity residual
Connecting with the Solow residual

- Using:
  \[ \Delta \log Y_t \equiv \frac{P^C C N}{P^Y Y} \Delta \log (C_t N_t) + \frac{P^I I}{P^Y Y} \Delta \log I_t \]
  
  we obtain (for \( \sigma < 1 \); similar expression for \( \sigma > 1 \)):
  
  \[ \frac{v}{\lambda p^Y y} \Delta \log \frac{V_t}{N_t} = E_t \sum_{s=0}^{\infty} \beta^s \Delta \log PR_{t+s} \]
  
  \[ + \sum_{s=0}^{\infty} \beta^s [E_t \log PR_{t+s} - E_{t-1} \log PR_{t+s}] \]
  
  \[ + \frac{1}{\beta} \frac{k}{p^Y y} \Delta \log \frac{K_{t-1}}{N_{t-1}} \]

- The LHS is the “income equivalent” of welfare growth
- \( \Delta \log PR_{t+s} \) denotes the Solow productivity residual in per-capita terms:

  \[ \Delta \log PR_{t+s} = \Delta \log \frac{Y_{t+s}}{N_{t+s}} - s_L \Delta \log L_{t+s} - s_K \Delta \log \frac{K_{t+s-1}}{N_{t+s-1}} \]
Cross-country analysis

- We compare welfare across countries from the perspective of the representative agent in a reference country.
- The agent is faced with the time paths of exogenous variables in a different country $i$, but evaluates the result using her own marginal rates of substitution.
- For instance, consider a US representative agent’s perspective and take a log-linear expansion around the US steady state. After some algebra, we get:

$$
\frac{v^{us}}{\lambda^{us} p^{Y,us} y^{us}} \left[ \log \frac{V^{i}_t}{N^{i}_t} - \log \frac{V^{us}_t}{N^{us}_t} \right] = E_t \sum_{s=0}^{\infty} \beta^s \left[ \log \bar{PR}^{i}_{t+s} - \log PR^{us}_{t+s} \right] + \frac{1}{\beta} \frac{k^{us}}{p^{Y,us} y^{us}} \left( \log \frac{K^{i}_{t-1}}{N^{i}_{t-1}} - \log \frac{K^{us}_{t-1}}{N^{us}_{t-1}} \right)
$$

where input and output shares are those of the reference country:

$$
\bar{PR}^{i}_{t+s} = \left( s^{us}_c \log C^{i}_{t+s} + s^{us}_i \log \frac{I^{i}_{t+s}}{N^{i}_{t+s}} \right) - s^{us}_L \log L^{i}_{t+s} - s^{us}_K \log \frac{K^{i}_{t+s-1}}{N^{i}_{t+s-1}}
$$
Implications (1): The outcome variable for positive and normative analysis

- To a first order, TFP as defined by Solow is a key determinant of welfare (the other determinant is capital)
- Thus, it should be the object we try to explain (or increase)–even when it does not equal technology!
- *Expectations* and thus *persistence* are an important part of the welfare contribution
Implications (2): Everything from the household side

- Made no assumptions regarding technology and firm behavior
- Thus the result is very general on those two dimensions
- Implication: All prices should be those perceived by households, not firms
Extensions: Taxes

- Let $\tau^K$ be the tax rate on capital income, $\tau^L$ the tax rate on labor income, and $\tau^C$ and $\tau^I$ the sales taxes/VAT rates for consumption and investment.
- Assume that the revenue so raised is distributed back to individuals using lump-sum transfers.
- Proceeding as before, we find:

$$\frac{v_t - v}{\lambda p^Y y} = E_t \sum_{s=0}^{\infty} \beta^s [\hat{y}_t - (1 - \tau^L) s_L \hat{L}_{t+s} - (1 - \tau^K) s_K \hat{k}_{t+s-1}]$$
$$+ \lambda \frac{1}{\beta} k \hat{k}_{t-1}$$

where value added is defined as:

$$\hat{y}_t = s_c \left(1 + \tau^C\right) \hat{c}_t + s_i \left(1 + \tau^I\right) \hat{i}_t$$

- Now the welfare-relevant TFP measure is:

$$\log PR_{t+s} = \log \frac{Y_{t+s}}{N_{t+s}} - (1 - \tau^L) s_L \log L_{t+s} - (1 - \tau^K) s_K \log \frac{K_{t+s-1}}{N_{t+s-1}}$$
Extensions: Open Economy (1)

- Reinterpret \( b_t \) as net foreign assets. We still find that:

\[
v_t - v = E_t \sum_{s=0}^{\infty} \beta^s \lambda \left[ p^C c_t + s_i i_t - p^L L_{t+s} - p^K k \hat{k}_{t+s-1} \right] + \frac{1}{\beta} k \hat{k}_{t-1}
\]

which can be re-written as:

\[
\frac{v_t - v}{\lambda p^a a} = E_t \sum_{s=0}^{\infty} \beta^s \left[ \hat{a}_t - s_L \hat{L}_{t+s} - s_K \hat{k}_{t+s-1} \right] + \frac{1}{\beta} \frac{k}{p^a a} \hat{k}_{t-1}
\]

where the concept of output is only domestic absorption, defined as:

\[
\hat{a}_t = s_c \hat{c}_t + s_i \hat{i}_t
\]

and \( s_c, s_i, s_L \) and \( s_K \) are shares out of domestic absorption.

- Then our main result holds for the open economy as well, provided one keeps using domestic absorption as the measure of output.
Suppose one wants to use a conventional measure of output, real GDP, defined as:

\[ \tilde{y}_t = s_c \hat{c}_t + s_i \hat{i}_t + s_x \hat{x}_t - s_m \hat{m}_t \]

Then, one obtains:

\[
\frac{v_t - v}{\lambda p^Y y} = E_t \sum_{s=0}^{\infty} \beta^s \left[ \tilde{y}_{t+s} - s_L \hat{L}_{t+s} - s_K \hat{k}_{t+s-1} \right. \\
+ \left( \frac{br / p^Y y}{(1+g)(1+n)} \hat{r}_{t+s} + s_x \hat{p}_{t+s}^x - s_m \hat{p}_{t+s}^m \right) \\
+ \frac{1}{\beta} \frac{k}{p^Y y} \hat{k}_{t-1} + \frac{1}{\beta} \frac{b}{p^Y y} \hat{b}_{t-1} \right]
\]

where \( s_c, s_i, s_L, s_x, s_m \) and \( s_K \) are shares out of total value added.

In this case we get the GDP-based Solow residual, but we need three additional terms: 1) terms of trade gains; 2) gains from changes in returns from foreign assets; 3) initial holdings of net foreign assets.

This version connects better with the existing literature based on GDP (e.g., Kohli [2004]), but is much harder to implement empirically.
DATA

- EU-KLEMS
  - Capital (value of capital stock and compensation to capital)
  - Labor (hours, labor service index and compensation to labor)
- Penn World Tables
  - Private Consumption
  - Government Consumption
  - Investment
- Boscá et al. (2005), Mendoza et al. (1994)
  - Effective tax rates on labor and capital
- Use univariate AR(1) and AR(2) equations to forecast future log TFP
Fiscal policy and the construction of welfare-relevant TFP

- Measures of output, and input shares, depend on assumptions about fiscal policy
- Experiment with two assumptions about government spending: \( s^*_c = s_c \) (optimal spending) and \( s^*_c = 0 \) (all spending is wasteful)
- Also examine two assumptions about taxes: lump-sum taxes and distortionary taxes
- Re-estimate the time-series process for TFP in each country for each set of assumptions
- We will display results assuming optimal spending and distortionary taxes
Figure: Cross-country welfare comparisons: log equivalent permanent consumption gap (vis-a-vis the U.S.)
Figure: Cross-country welfare comparisons: log equivalent permanent consumption gap (vis-a-vis the U.S.). French preferences.
**Table:** Per-Capita GDP, Consumption and Equivalent Consumption relative to USA: 1985, 2005 and Average

<table>
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<th>Consumption</th>
<th>GDP</th>
<th>Equivalent Consumption</th>
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<td></td>
<td></td>
<td></td>
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<tr>
<td>Canada</td>
<td>-0.179</td>
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<tr>
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<tr>
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<td>UK</td>
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<tr>
<td><strong>PANEL B: 2005</strong></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Canada</td>
<td>-0.324</td>
<td>-0.177</td>
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<tr>
<td>France</td>
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<tr>
<td>UK</td>
<td>-0.190</td>
<td>-0.219</td>
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Table: Components of Welfare Gap Relative to USA: 1985, 2005 and Average

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<td>% TFP % K</td>
<td>% TFP % K</td>
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**PANEL A: 1985**

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<tbody>
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<td>1.006 -0.006</td>
<td>1.006 -0.006</td>
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<td>Japan</td>
<td>1.091 -0.091</td>
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<td>Spain</td>
<td>0.855 0.145</td>
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<td>UK</td>
<td>0.379 0.621</td>
<td>0.672 0.328</td>
<td>0.683 0.317</td>
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**PANEL B: 2005**

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<td>0.910 0.090</td>
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<td>UK</td>
<td>- -</td>
<td>-0.079 1.079</td>
<td>-0.233 1.233</td>
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Notes: Beta = 0.95 for all countries.
Summary of cross country results

- In 1985, the UK and France trail the US by a relatively small amount. This gap increases for France and decreases for the UK.
- Large welfare gap from US in 1985 for the other countries. With the exception of Spain, these gaps increase over time.
- TFP responsible for most of the welfare gap relative to US.
- Taking France as reference country does not affect the rankings, but other countries are shifted down vis-a-vis the US.
- Comparing welfare and PPP-adjusted consumption:
  - The US is atop the world rankings in both cases.
  - Rankings are quite different for other countries. For instance, France trails the US by 40% in consumption per capita, but by 20% in equivalent consumption per-capita.
Conclusions

• The Solow productivity residual is key to measuring welfare.

• To a first order, just two pieces of data — the EPDV of the Solow residual and the capital stock — are a sufficient statistic for the welfare of a representative consumer.

• This result allows us to make quantitative comparisons of welfare gaps among countries and welfare growth over time.

• Future work: Second-order approximations, inequality, human capital accumulation.
### Table: Welfare Gap Relative to USA: 1985, 2005 and Average

<table>
<thead>
<tr>
<th></th>
<th>Wasteful Spending Lump-Sum Taxes</th>
<th>Wasteful Spending Distortionary Taxes</th>
<th>Optimal Spending Distortionary Taxes</th>
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<tr>
<td>Canada</td>
<td>-0.256</td>
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