# 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
  Weitzman (1976, 2003), Basu and Fernald (2002), Hulten and Schreyer (2010)
- 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

$$V_t \equiv E_t \sum_{s=0}^{\infty} \beta^s U(C_{t+s}, \overline{L} - L_{t+s})$$

- Budget constraint

$$\begin{aligned} P_t^I K_t + B_t &= (1-\delta) P_t^I K_{t-1} + (1+i_t) B_{t-1} + P_t^L L_t N_t + P_t^K K_t + \\ &+ \Pi_t - P_t^C C_t N_t \end{aligned}$$

# 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):

$$\begin{aligned} v_t &= v + E_t \sum_{s=0}^{\infty} \beta^s \lambda [p^L L \widehat{p}^L_{t+s} + \frac{p^K k}{(1+g)(1+n)} \widehat{p}^K_{t+s} - p^C c \widehat{p}_{t+s} + \pi \widehat{\pi}_{t+s} \\ &\quad + \frac{rb}{(1+g)(1+n)} \widehat{r}_{t+s})] + \lambda \frac{1}{\beta} k \widehat{k}_{t-1} + \lambda \frac{(1+r)}{(1+g)(1+n)} b \widehat{b}_{t-1} \end{aligned}$$

- 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:

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

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

# Connecting with the Solow residual

- Using:

$$\Delta \log Y_t \equiv \frac{P^C CN}{P^Y Y} \Delta \log (C_t N_t) + \frac{P^I I}{P^Y Y} \Delta \log I_t$$

we obtain (for $\sigma < 1$; similar expression for $\sigma > 1$):

$$\begin{aligned} \frac{v}{\lambda p^Y y} \Delta \log \frac{V_t}{N_t} &= E_t \sum_{s=0}^{\infty} \beta^s \Delta \log PR_{t+s} \\ &+ \sum_{s=0}^{\infty} \beta^s \left[ E_t \log PR_{t+s} - E_{t-1} \log PR_{t+s} \right] \\ &+ \frac{1}{\beta} \frac{k}{p^y y} \Delta \log \frac{K_{t-1}}{N_{t-1}} \end{aligned}$$

- 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:

$$\frac{v^{us}}{\lambda^{us} p^{Y,us} y^{us}} \left[ \log \frac{V_t^i}{N_t^i} - \log \frac{V_t^{us}}{N_t^{us}} \right] = E_t \sum_{s=0}^{\infty} \beta^s \left[ \log \overline{PR}_{t+s}^i - \log PR_{t+s}^{us} \right] + \frac{1}{\beta} \frac{k^{us}}{p^{Y,us} y^{us}} \left( \log \frac{K_{t-1}^i}{N_{t-1}^i} - \log \frac{K_{t-1}^{us}}{N_{t-1}^{us}} \right)$$

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

$$\overline{PR}_{t+s}^i = \left( s_c^{us} \log C_{t+s}^i + s_i^{us} \log \frac{I_{t+s}^i}{N_{t+s}^i} \right) - s_L^{us} \log L_{t+s}^i - s_K^{us} \log \frac{K_{t+s-1}^i}{N_{t+s-1}^i}$$

# 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:

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

where value added is defined as:

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

- Now the welfare-relevant TFP measure is:

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

# Extensions: Open Economy (1)

- Reinterpret $b_t$ as net foreign assets. We still find that:

$$v_t - v = E_t \sum_{s=0}^{\infty} \beta^s \lambda \left[ p^C c \widehat{c}_{t+s} + i \widehat{i}_{t+s} - p^L L \ \widehat{L}_{t+s} - p^K k \ \widehat{k}_{t+s-1} \right] + \frac{1}{\beta} k \widehat{k}_{t-1}$$

  which can be re-written as:

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

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

$$\widehat{a}_t = s_c \widehat{c}_t + s_i \widehat{i}_t$$

  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

# Extensions: Open Economy (2)

- Suppose one wants to use a conventional measure of output, real GDP, defined as:

$$\widehat{y}_t = s_c \widehat{c}_t + s_i \widehat{i}_t + s_x \widehat{x}_t - s_m \widehat{m}_t$$

- Then, one obtains:

$$\begin{aligned} \frac{v_t - v}{\lambda p^Y y} = & E_t \sum_{s=0}^{\infty} \beta^s [\widehat{y}_{t+s} - s_L \widehat{L}_{t+s} - s_K \widehat{k}_{t+s-1} \\ & + (\frac{br/p^Y y}{(1+g)(1+n)} \widehat{r}_{t+s} + s_x \widehat{p}^x_{t+s} - s_m \widehat{p}^m_{t+s})] \\ & + \frac{1}{\beta} \frac{k}{p^Y y} \widehat{k}_{t-1} + \frac{1}{\beta} \frac{b}{p^Y y} \widehat{b}_{t-1} \end{aligned}$$

  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: $s^*_{c_G} = s_{c_G}$ (optimal spending) and $s^*_{c_G} = 0$ (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.)

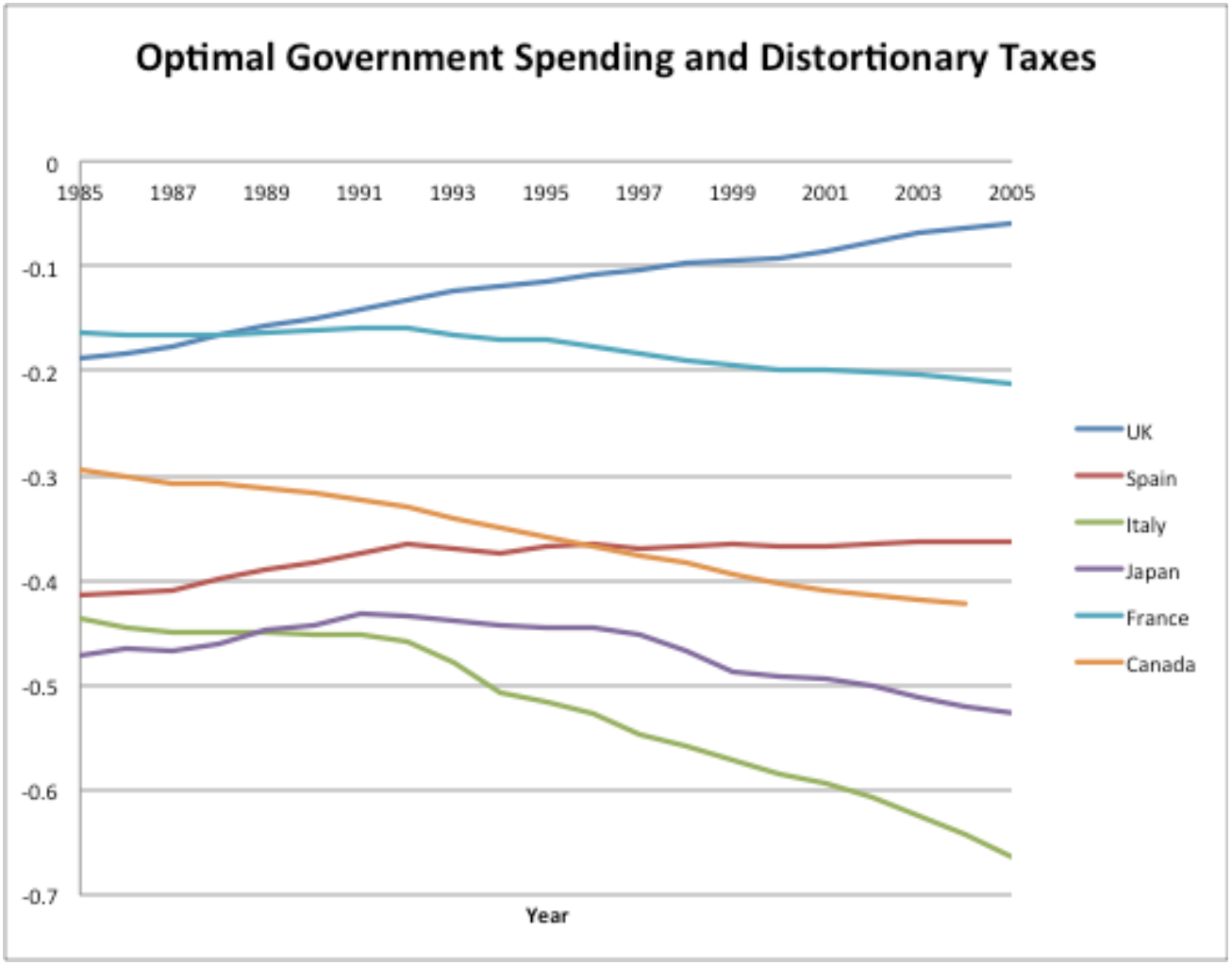

Figure: Cross-country welfare comparisons: log equivalent permanent consumption gap (vis-a-vis the U.S.). French preferences.

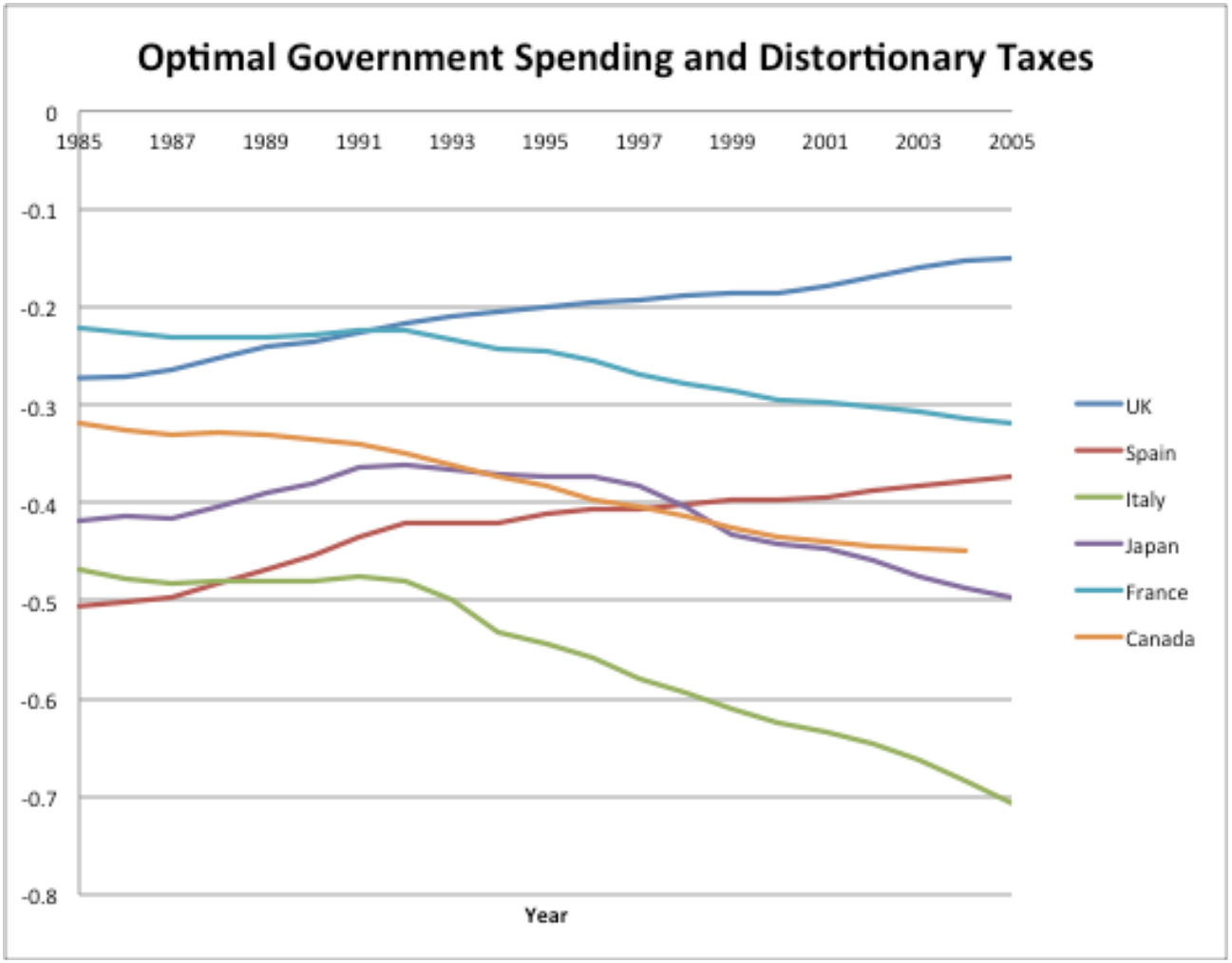

Table: Per-Capita GDP, Consumption and Equivalent Consumption relative to USA: 1985, 2005 and Average

| | *Consumption* | *GDP* | Equivalent Consumption |
|---|---|---|---|
| *PANEL A: 1985* | | | |
| Canada | -0.179 | -0.106 | -0.295 |
| France | -0.285 | -0.250 | -0.165 |
| Italy | -0.378 | -0.287 | -0.437 |
| Japan | -0.434 | -0.211 | -0.471 |
| Spain | -0.624 | -0.570 | -0.414 |
| UK | -0.306 | -0.304 | -0.189 |
| USA | 0.000 | 0.000 | 0.000 |
| *PANEL B: 2005* | | | |
| Canada | -0.324 | -0.177 | -0.451 |
| France | -0.401 | -0.317 | -0.213 |
| Italy | -0.501 | -0.370 | -0.664 |
| Japan | -0.456 | -0.261 | -0.526 |
| Spain | -0.527 | -0.419 | -0.362 |
| UK | -0.190 | -0.219 | -0.059 |
| USA | 0.000 | 0.000 | 0.000 |

Table: Components of Welfare Gap Relative to USA: 1985, 2005 and Average

| | Wast. Spending L-S Taxes | | Wast. Spending Dist. Taxes | | Opt. Spending Dist. Taxes | |
|---|---|---|---|---|---|---|
| | *% TFP* | *% K* | *% TFP* | *% K* | *% TFP* | *% K* |
| *PANEL A: 1985* | | | | | | |
| Canada | 0.936 | 0.064 | 0.945 | 0.055 | 0.945 | 0.055 |
| France | 0.968 | 0.032 | 0.988 | 0.012 | 0.987 | 0.013 |
| Italy | 1.007 | -0.007 | 1.006 | -0.006 | 1.006 | -0.006 |
| Japan | 1.091 | -0.091 | 1.096 | -0.096 | 1.099 | -0.099 |
| Spain | 0.855 | 0.145 | 0.880 | 0.120 | 0.885 | 0.115 |
| UK | 0.379 | 0.621 | 0.672 | 0.328 | 0.683 | 0.317 |
| *PANEL B: 2005* | | | | | | |
| Canada | 0.900 | 0.100 | 0.911 | 0.089 | 0.910 | 0.090 |
| France | 0.421 | 0.579 | 0.811 | 0.189 | 0.788 | 0.212 |
| Italy | 0.972 | 0.028 | 0.975 | 0.025 | 0.976 | 0.024 |
| Japan | 1.065 | -0.065 | 1.060 | -0.060 | 1.067 | -0.067 |
| Spain | 0.898 | 0.102 | 0.900 | 0.100 | 0.888 | 0.112 |
| UK | - | - | -0.079 | 1.079 | -0.233 | 1.233 |

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

| | Wasteful Spending Lump-Sum Taxes | Wasteful Spending Distortionary Taxes | Optimal Spending Distortionary Taxes |
|---|---|---|---|
| *PANEL A: 1985* | | | |
| Canada | -0.256 | -0.294 | -0.295 |
| France | -0.069 | -0.176 | -0.165 |
| Italy | -0.368 | -0.420 | -0.437 |
| Japan | -0.511 | -0.488 | -0.471 |
| Spain | -0.327 | -0.396 | -0.414 |
| UK | -0.096 | -0.182 | -0.189 |
| USA | 0.000 | 0.000 | 0.000 |
| *PANEL B: 2005* | | | |
| Canada | -0.407 | -0.455 | -0.451 |
| France | -0.078 | -0.240 | -0.213 |
| Italy | -0.569 | -0.641 | -0.664 |
| Japan | -0.540 | -0.582 | -0.526 |
| Spain | -0.396 | -0.405 | -0.362 |
| UK | 0.034 | -0.068 | -0.059 |
| USA | 0.000 | 0.000 | 0.000 |

Notes: Beta=0.95 for all countries.