The Mystery of TFP

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Causes of (measured) aggregate TFP growth

1. Technical and scientific progress (including improvements in management techniques).
2. Learning effects, either learning by doing or learning from others, or more broadly externalities; economies of scale.
3. Reallocation of inputs towards more (or less) productive uses, either at the firm or the industry level.
4. Measurement error, e.g.
   - if increases in the quality of human or physical capital are wrongly ignored
   - or if output is mis-measured
   - or when some types of asset (such as intangibles) are wrongly omitted.

Solow (REcStats 1957); Hulten (2001)

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5. Shifts in the structure of output and demand leading to changes in the aggregate growth rate of TFP and hence of aggregate labour productivity. These shifts could be favourable or unfavourable.

Baumol (AER, 1967); Oulton (OEP, 2001)

Questions considered in this presentation

- Has structural change been favourable or unfavourable to growth?
- Is capital mis-measured?
- Is the true elasticity of output with respect to capital (the capital elasticity) higher than capital's share? If so, TFP growth is *overstated*.
- Does TFP growth cause capital growth?
- Is TFP growth persistent?

Data

- Source: EU KLEMS (www.euklems.net).
- 18 countries with data on TFP growth.
- Maximum period for TFP growth: 1971-2007.
- 10 industry groups collectively making up the market (business) sector.
- So imputed rent of home-owners, health, education and government excluded (25% of GDP).

O'Mahony and Timmer (EJ, 2009)

Countries and periods

Code	Country name	First year	Last year	Number of years
AUS	Australia	1983	2007	25
AUT	Austria	1981	2007	27
BEL	Belgium	1981	2006	26
CZE	Czech Republic	1996	2007	12
DNK	Denmark	1981	2007	27
ESP	Spain	1981	2007	27
FIN	Finland	1971	2007	37
FRA	France	1981	2007	27
GER	Germany	1992	2007	16
HUN	Hungary	1996	2007	12
IRL	Ireland	1989	2007	19
ITA	Italy	1971	2007	37
JPN	Japan	1974	2006	33
NLD	Netherlands	1980	2007	28
SVN	Slovenia	1996	2006	11
SWE	Sweden	1994	2007	14
UK	United Kingdom	1971	2007	37
USA	United States	1978	2007	30

The 10 sectors included in the study

Sector code	Sector description	Value added share of GDP, %	Share of total (whole economy) hours, %
A & B	Agriculture, hunting and forestry. Fishing	4.3	8.3
C	Mining & quarrying	1.4	0.5
D	Manufacturing	22.1	21.1
E	Electricity, gas & water	2.4	0.9
F	Construction	6.6	8.0
G	Wholesale & retail trade; repair of motor vehicles, motorcycles, and personal and household goods	11.9	15.3
H	Hotels & restaurants	2.4	4.1
I	Transport, storage and communications	7.3	6.6
J	Financial intermediation	5.1	2.9
K (exc. 70)	Business services	7.1	7.0
A-K (exc. 70)	Market sector	70.6	74.6
A-Q	Whole economy (GDP)	100.0	100.0

Shares are unweighted means across 18 countries and time.

Why industry data from EU KLEMS?

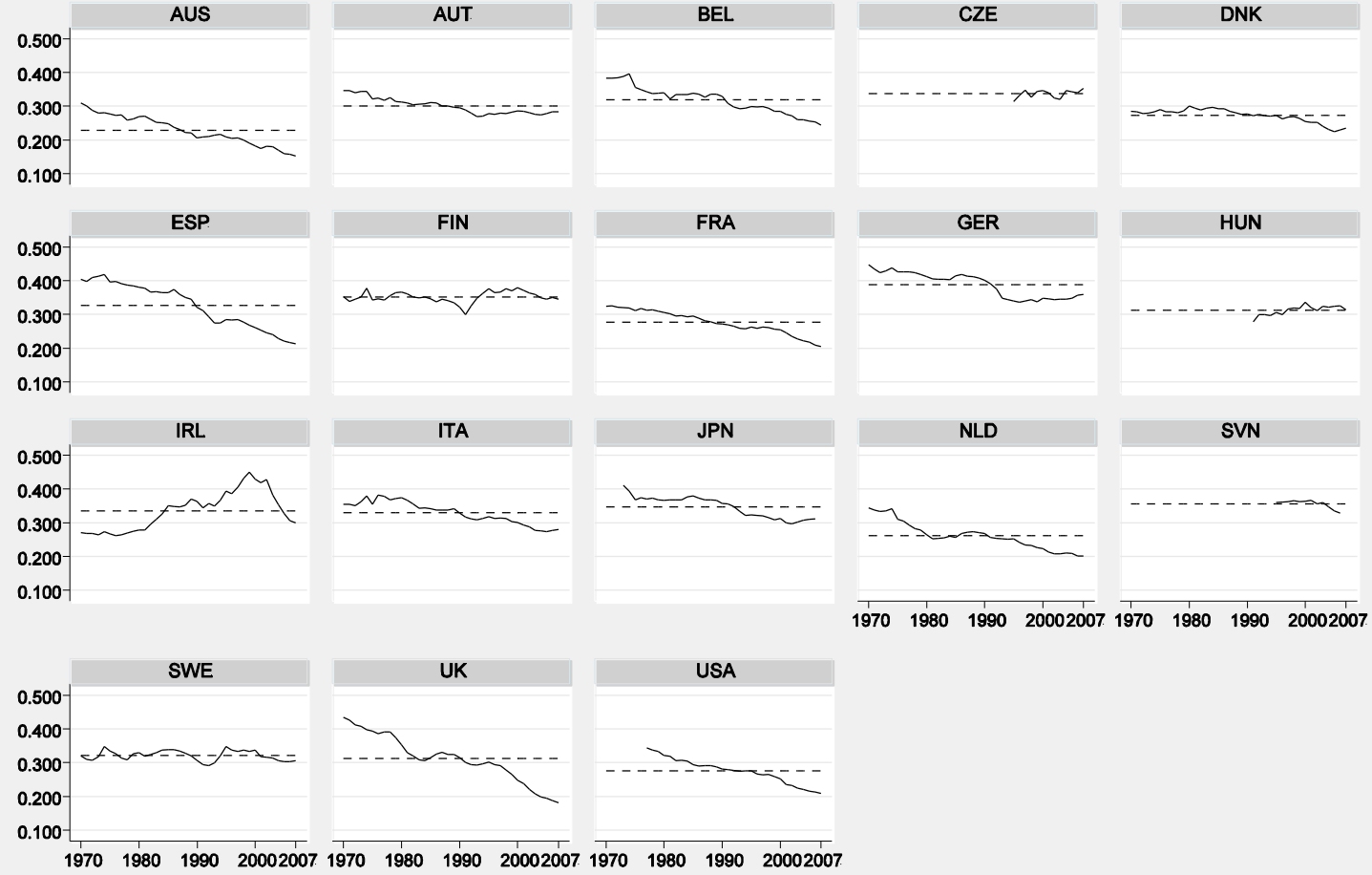
- The industry data is consistent with the national accounts of each country.
- In EU KLEMS labour and capital are measured in a detailed and consistent way. Labour is measured by hours worked broken down by education, age and sex. Capital, measured by the PIM, is broken down into 7 types (3 ICT and 4 non-ICT).
- In micro data labour and capital are often crudely measured, e.g. heads not hours for labour and no breakdown by type. Capital is often measured by book value, with no breakdown by type.

Structural change

In all countries, resources have been shifting towards industries with lower than average TFP growth (Finance) or even negative TFP growth (Business services). But TFP growth in the market sector generally shows no long run tendency to decline.

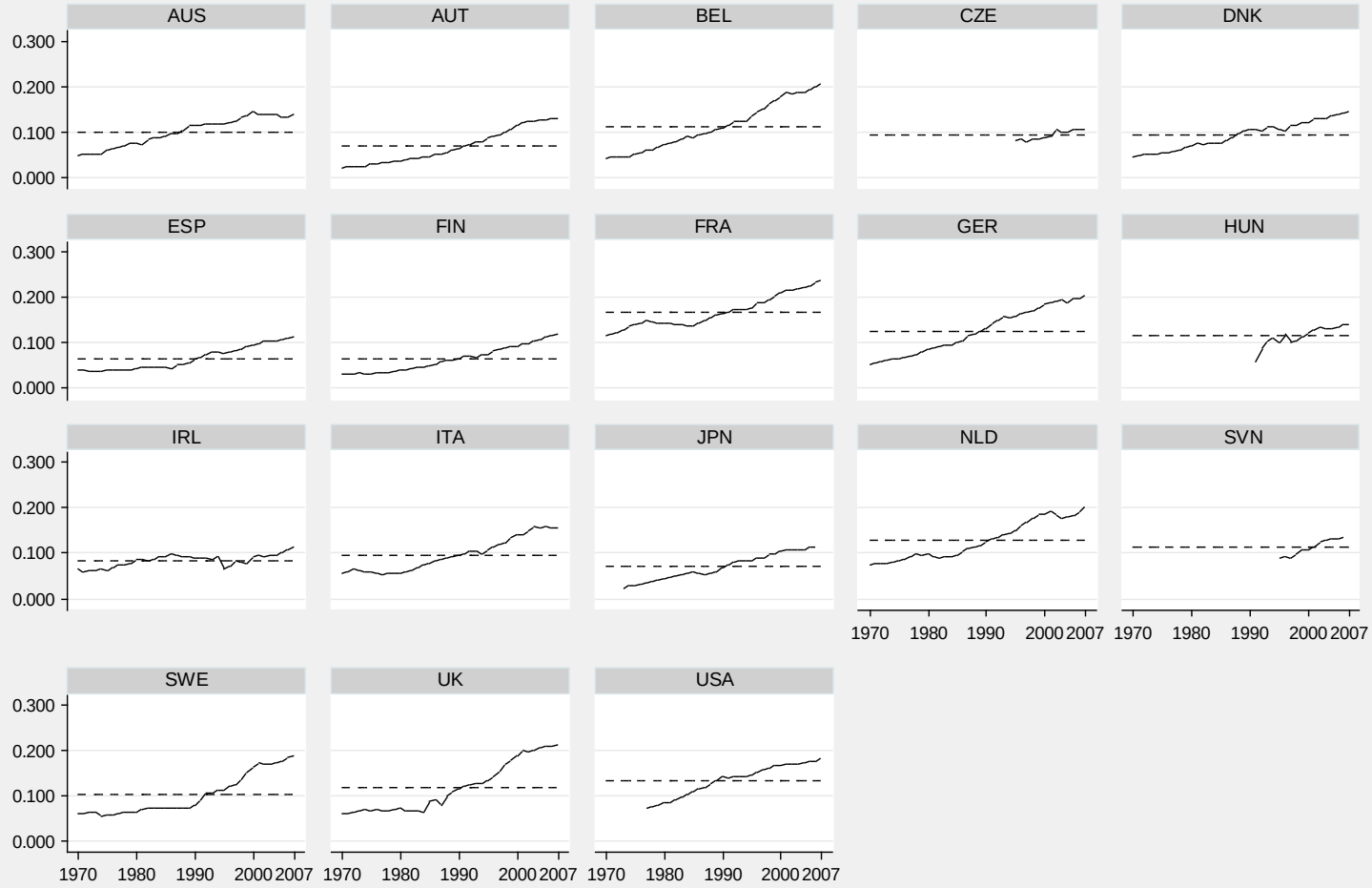
How is this possible?

Value added share of Manufacturing (D) in market sector GDP



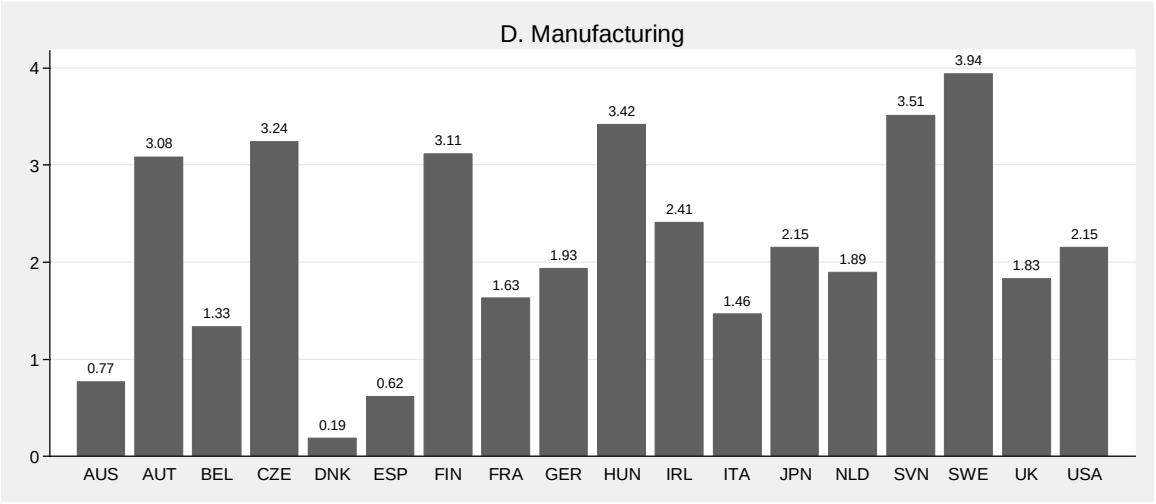
Source: EU KLEMS. Note: Dashed lines denote country means.

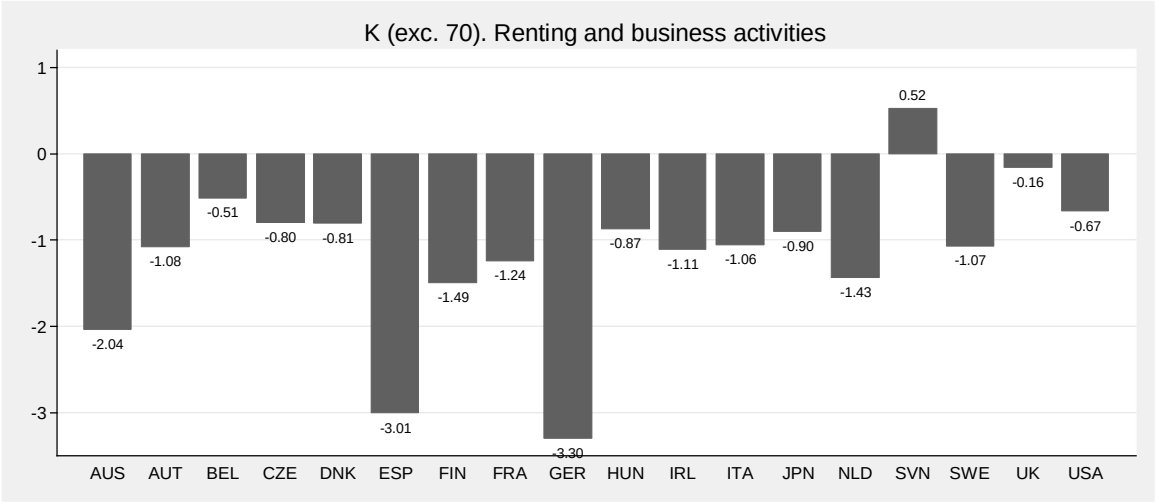
Value added share of Business services (K, exc. 70) in market sector GDP



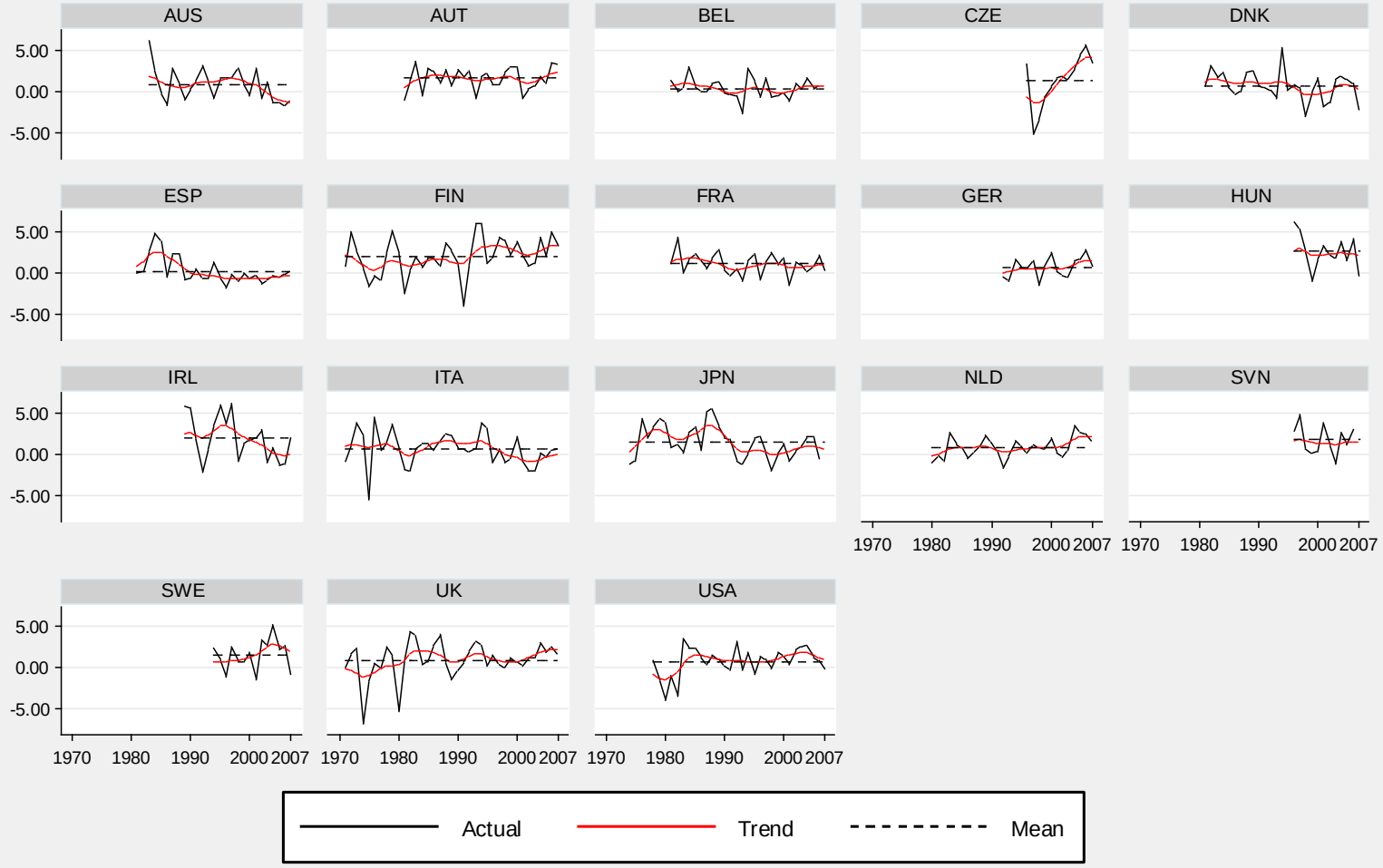
Source: EU KLEMS. Note: Dashed lines denote country means.

Mean TFP growth rates, % p.a., by country





Growth of TFP in the market sector (A-K), % p.a.



Source: EU KLEMS.
Note: Trend growth rate is that of HP-smoothed TFP level. Dashed lines denote country means of actual TFP growth rate.

Baumol's (AER, 1967) cost disease model

- Suppose output grows at the same rate in all industries but some industries (e.g. services) have lower TFP growth than others (e.g. manufacturing). Then resources shift to slow-productivity-growth services and overall TFP (and LP growth) *slows down*.
- But this argument is couched in terms of *final* services (private or public). What about *intermediate* services? (Oulton, OEP, 2001).

Aggregate and industry TFP growth

Aggregate (top down) measure of TFP growth:

$$\mu := \hat{V} - \alpha\hat{K} - (1-\alpha)\hat{L}$$

V : real value added (GDP); μ: TFP growth

Aggregate and industry TFP growth

Top down measure of aggregate TFP growth:

$$\mu := \hat{V} - \alpha\hat{K} - (1-\alpha)\hat{L} \qquad V: \text{real value added (GDP)};\ \mu: \text{TFP growth}$$

Bottom up measure of aggregate TFP growth is

a Domar-weighted *sum* (not average) of *industry* TFP growth rates:

$$\mu = \sum_{i=1}^{N} d_i \mu_i^{GO}$$

where $d_i := \left[\frac{GO_i}{GDP}\right]$, the Domar weights

and $$\mu_i^{GO} := \hat{Y}_i - \sum_{k=1}^{C} \alpha_{ik}\hat{K}_{ik} - \sum_{l=1}^{D} \beta_{il}\hat{L}_{il} - \sum_{j=1}^{N} m_{ij}\hat{M}_{ij}$$

Simple algebra shows that top down and bottom up measures are identically equal.

Domar (EJ, 1961); Hulten, RES, 1978; Jorgenson et al. (1987); Gabaix, Econometrica, 2011.

Aggregate and industry TFP growth, cont.

Alternatively, we can use the value added concept of TFP growth:

$$\mu_i^{VA} := \hat{V}_i - \sum_{k=1}^{C} \alpha_{ik}^{VA} \hat{K}_{ik} - \sum_{l=1}^{D} \beta_{il}^{VA} \hat{L}_{il}$$

Simple algebra shows that:

$$\mu_i^{VA} = \left[\frac{GO_i}{VA_i} \right] \mu_i^{GO}$$

Hence we get the alternative aggregation scheme:

$$\mu = \sum_{i=1}^{N} v_i \mu_i^{VA} \qquad v_i : \text{value added share of ith industry in GDP}$$

Implications of Domar aggregation

$$\mu = \sum_{i=1}^{N} d_i \mu_i^{GO}$$

1. The Domar weights do not sum to 1 (generally the sum is between 2 and 3).
2. One Domar weight can increase without any other weight necessarily decreasing.
3. For given TFP growth rates, a rise in the Domar weight for the ith industry will raise the aggregate TFP growth rate, *provided TFP growth in the ith industry is positive.*
4. A shift in resources from high TFP growth to low (but positive) TFP growth industries can *raise*, not lower, the aggregate TFP growth rate.

Simple two-sector model

- Closed economy, two sectors: Cars and Business services (BuS)
- Car industry makes only final sales.
- Business services makes only intermediate sales (to the car industry).
- Cars uses K, L, and BuS as inputs.
- BuS uses only K and L as inputs.

Growth accounting in the simple two-sector model

$$\mu = d_{Cars} * \mu_{Cars}^{GO} + d_{BuS} * \mu_{BuS}^{GO} \qquad \mu_{Cars}^{GO} > 0,\ \mu_{BuS}^{GO} > 0$$

where

$$d_{Cars} = \frac{GO_{Cars}}{GDP} = \frac{Final\ sales\ of\ cars}{GDP} = 1$$

and

$$d_{BuS} = \frac{GO_{BuS}}{GDP} = \frac{Intermediate\ sales\ to\ Cars}{GDP} = \frac{GO_{Cars} - VA_{Cars}}{GO_{Cars}}$$

$$= 1 - \frac{VA_{Cars}}{GO_{Cars}}$$

Increased outsourcing as a source of growth

Suppose there is *increasing* outsourcing by the car industry, i.e. GO/VA is rising in cars.

Then d_{BuS} is rising even though d_{Cars} is constant. I.e. the sum of the Domar weights increases.

So for given (gross output) TFP growth in Cars and Business services, aggregate μ *rises*.

And this is true even if TFP growth in BuS is *lower* than in Cars.

(Using the value added concept, TFP growth is rising in cars, constant in BuS, and rising overall since contribution of Cars is constant).

In summary …

Domar weight on BuS can rise, with everything else on RHS constant. So μ rises.

$$\Uparrow \qquad \qquad \Uparrow$$
$$\mu = (d_{Cars}) * \mu_{Cars}^{GO} + (d_{BuS}) * \mu_{BuS}^{GO} \qquad \mu_{BuS}^{GO} > 0$$

Baumol (AER, 1967); Oulton (OEP, 2001); Baumol in Krueger (JEP, 2001)

Intuition

As long as TFP growth in Business services is positive, the price of providing these services is falling relative to the price in the Car industry of providing them in-house. If demand for Business services is elastic then their share in total costs of the car industry will rise.

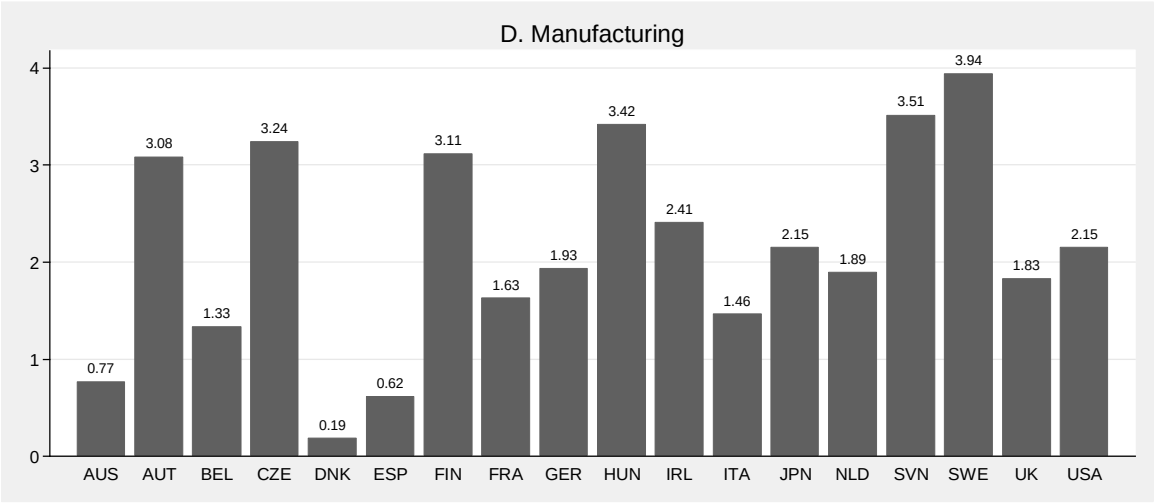
In practice, Business services includes some very sophisticated and high-tech products (design, accountancy, legal, management, computer, etc).

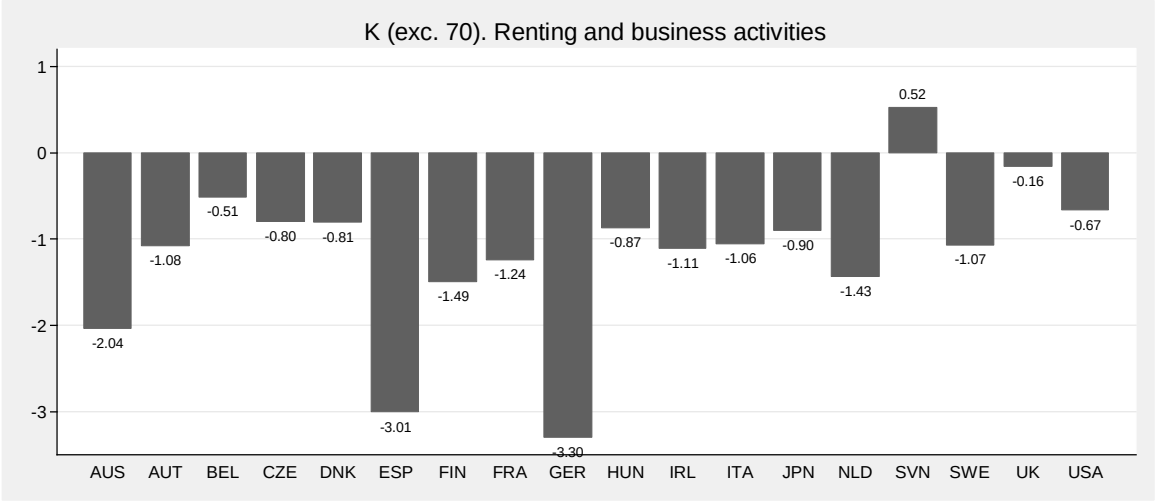
Changes in Domar weights between first year and last year

	Sections			
	A-F	G,H	I,J,K	Sum
Australia	-0.255	0.151	0.227	0.123
Austria	-0.086	0.035	0.275	0.224
Belgium	-0.104	0.117	0.371	0.384
Czech Republic	0.179	0.005	0.124	0.308
Denmark	-0.308	-0.024	0.369	0.037
Spain	-0.525	0.050	0.192	-0.283
Finland	-0.022	0.050	0.272	0.300
France	-0.290	0.062	0.297	0.069
Germany	0.130	-0.008	0.177	0.299
Hungary	0.152	0.011	0.086	0.249
Ireland	-0.246	-0.027	0.306	0.033
Italy	0.003	0.182	0.369	0.554
Japan	-0.507	0.042	0.222	-0.243
Netherlands	-0.356	0.065	0.268	-0.023
Slovenia	-0.043	-0.017	0.090	0.030
Sweden	0.054	0.011	0.079	0.144
United Kingdom	-0.697	0.118	0.452	-0.127
United States	-0.458	0.003	0.300	-0.155
Mean	-0.188	0.046	0.249	0.107
No. negative	13	4	0	5

A-F: production
G,H: consumer services
I,J,K: business-related services

But now there's a problem …
Mean TFP growth rates, % p.a., by country





Calculating the effect on TFP

- TFP growth in Business services is *negative* ---very implausible. Good price indices are lacking.
- So set it equal to mean TFP growth rate in the market sector in each country in each year. Adjust the TFP growth rates of other industries so that average is **unchanged**. (Conservative assumption: aggregate TFP growth rate is correct, offsetting errors at industry level).
- Now calculate what TFP growth in the market sector would have been if the Domar weights had been constant at
  - (a) those of the *beginning* of the sample period *or*
  - (b) those of the *end* of the sample period.
- The difference [(b) minus (a)] is the effect of structural change.

The effect of structural change on TFP growth: contribution of Business services and total

Country	Business services	Total
Australia	0.04	-0.01
Austria	0.15	0.13
Belgium	0.05	-0.05
Czech Republic	0.03	0.40
Denmark	0.06	0.31
Spain	0.01	-0.24
Finland	0.18	0.18
France	0.11	0.08
Germany	0.04	0.15
Hungary	0.07	0.16
Ireland	0.08	0.13
Italy	0.06	-0.17
Japan	0.09	0.02
Netherlands	0.07	0.08
Slovenia	0.03	-0.17
Sweden	0.09	0.25
United Kingdom	0.16	-0.33
United States	0.09	-0.37
Mean (unweighted)	*0.08*	*0.03*

TFP growth in Business services set equal to market sector average in each country. Other sectors adjusted to keep market sector average the same.

Results

- 11 out of 18 countries show a positive effect of structural change. And the average boost to growth for these 11 was 0.17% per year.
- The actual TFP growth rate amongst these 11 was 1.4% per year, so the boost is significant.
- 7 countries show a negative effect.

Conclusions

- The shift to Business services has had a **positive** effect on TFP growth in **all** countries (+0.08% per year).
- Overall, structural change has been **positive** in 11/18 countries.
- So the positive effect of Business services was offset by **negative** effects in 7/18 countries.
- These conclusions rely on upwardly adjusting TFP growth rates in Business services to the market sector average.
- This highlights the need for better measurement of industry output.
- Similar considerations apply to Finance.

THE END

Questions considered in this paper

- Is the empirical evidence on TFP consistent with the causes that theory considers important?
- How important is each source of TFP growth, particularly the fifth?

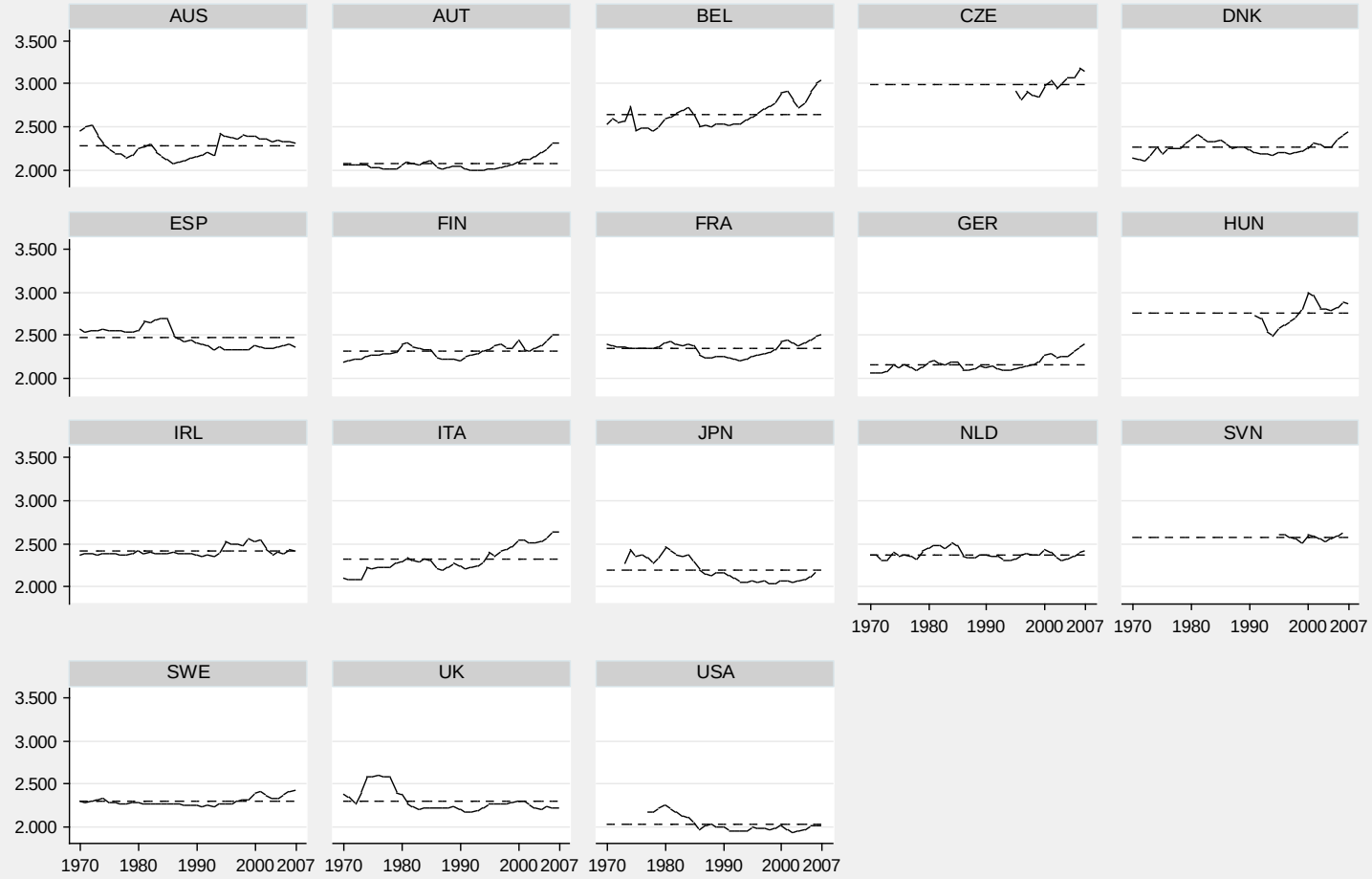
The Domar sum

$$d_i = \frac{GO_i}{GDP} = \left[\frac{GO_i}{VA_i}\right]\left[\frac{VA_i}{GDP}\right]$$

$$\sum_{i=1}^{N} d_i = \sum_{i=1}^{N}\left[\frac{GO_i}{VA_i}\right]\left[\frac{VA_i}{GDP}\right]$$

So the Domar sum is a weighted average of the degree of outsourcing (GO/VA) in the economy.

Sum of Domar weights



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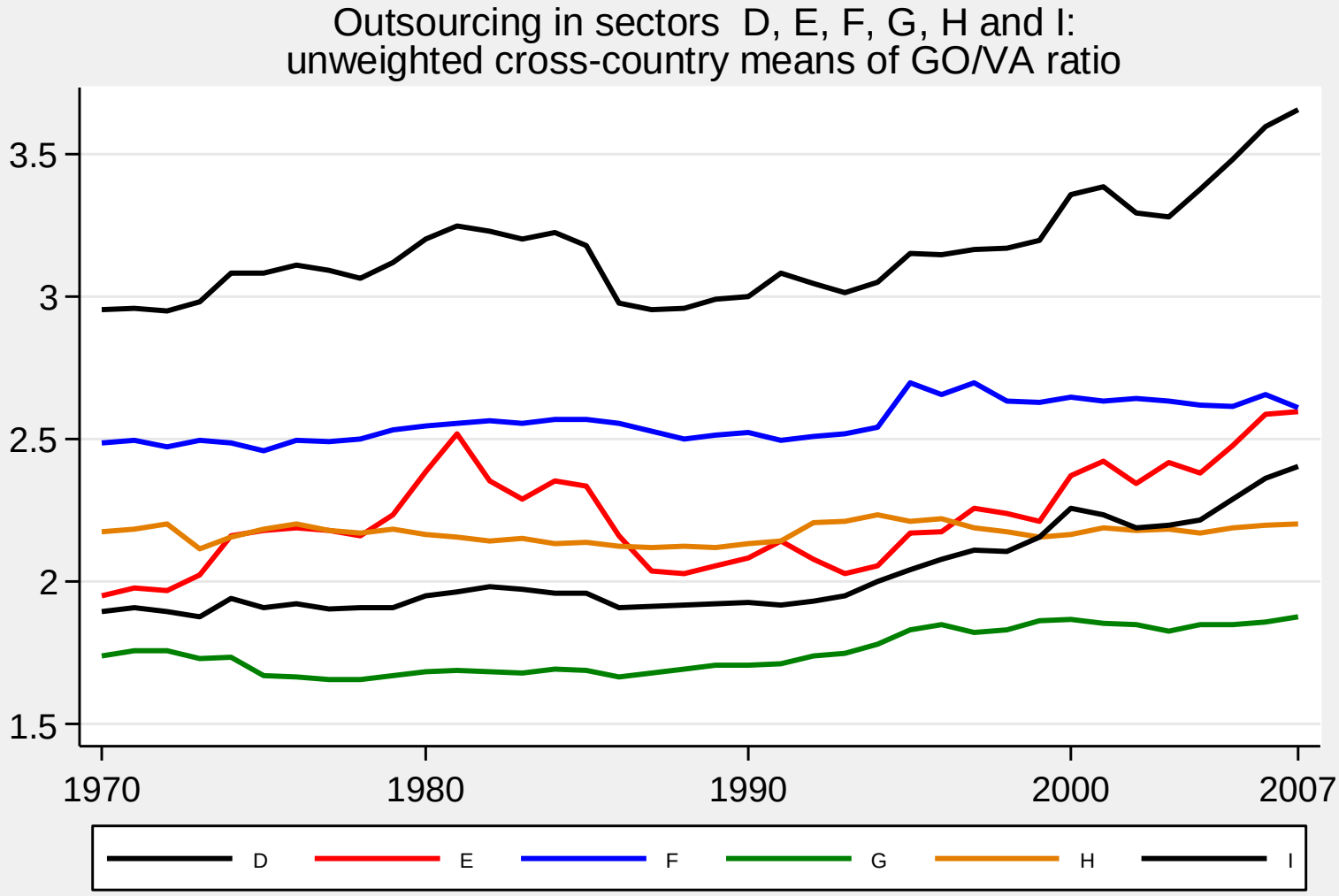

Source: EU KLEMS.

Persistence of TFP

- TFP growth is positively serially correlated at the aggregate (market sector) level but not at the industry level. This is a problem for theories which ascribe TFP growth to innovation: innovations take time to spread.

(Lack of) persistence in TFP growth
Dependent variable is TFP growth
18 countries, 1970-2007

	10 sectors	Market sector
TFP growth (lagged once)	0.0180	0.2310 ***
	(0.0280)	(0.0549)
Observations	4,450	425
R squared	0.057	0.325

Country and year dummies included; sector dummies included in 10 sectors regression.
OLS estimates with robust standard errors. *** significant at 1% level.

Persistence of TFP

- TFP growth is positively serially correlated at the aggregate (market sector) level but not at the industry level. This is a problem for theories which ascribe TFP growth to innovation: innovations take time to spread.
- Explanation: there are errors in the measurement of industry nominal value added which cancel out in the aggregate.

Errors-in-variables model

g_{ijt} : Measured TFP growth in j-th sector of i-th country in year t

$\tilde{g}_{ijt}$: True TFP growth

η_{ijt} : Measurement error

v_{ijt} : Value added share

1. $\tilde{g}_{ijt} = \beta \tilde{g}_{ijt-1} + Controls + \tilde{\varepsilon}_{ijt}$ (Hypothesis)
2. $g_{ijt} = \tilde{g}_{ijt} + \eta_{ijt}$, $E\eta_{ijt}\eta_{ijt-s} = 0$ (Measurement error)
3. $\sum_{i=1}^{N} v_{ijt}\eta_{ijt} = 0$ (Errors cancel out in aggregate)
4. $g_{it}^{MS} = \sum_{j=1}^{N} v_{ijt} g_{ijt}$ (Aggregation to MS level)

Errors in variables model, cont.

Then the regression equation

$$g_{ijt} = \beta g_{ij,t-1} + Controls + \varepsilon_{ijt}$$

has the classic errors-in-variables form: the independent variable is correlated with the error term, so the estimate of beta is biased towards zero.

But there is no such bias if we run the regression at the aggregate (market sector) level:

$$g_{it}^{MS} = \beta g_{i,t-1}^{MS} + Controls + \varepsilon_{it}^{MS}$$

Where do the errors come from?

- The growth of industry value added is much more volatile than the growth of industry input (K and L).
- If the national accounts on the income/output side are balanced year-by-year using a control total from the expenditure side, this could lead to errors in industry-level nominal value added.
- Conclusion: TFP is probably persistent at the sector level too.

Mismeasurement of capital

- Mismeasurement of quality change
- Missing assets
- Increasing variety

Mismeasurement of quality change in capital goods

At the aggregate level this may not matter much in large, rich countries. Reason:

1. GDP growth:

$\hat{Y} = w_C \hat{Y}_C + w_I \hat{Y}_I \quad w_C (w_I)$: shares of C (I) in GDP

2. Aggregate TFP growth:

$\mu = w_C \hat{Y}_C + w_I \hat{Y}_I - \alpha \hat{K} - (1-\alpha)\hat{L}$

3. Error in capital measurement:

$e = \hat{\tilde{K}} - \hat{K} \quad \hat{\tilde{K}}$: true growth rate of K

4. Then assuming $\hat{Y}_I = \hat{K}$, TFP error = $(w_I - \alpha)e < 0$ if $e > 0$ and $\alpha > w_I$

But at industry level or in an open economy importing high-tech capital goods, the error could be larger