Input-biased technical progress and the aggregate elasticity of substitution: Evidence from 14 EU Member States

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University of Dundee

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Background & Motivation

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- The *elasticity of substitution*
- The *direction of technical progress*

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  - sustainability of growth
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  - effectiveness of employment-creation policies
  - changes in factor income shares over time
  - sustainability of growth
- The *direction of technical progress* has been associated with:
  - welfare consequences of new technologies
  - changes in factor income shares

(Adapted from León-Ledesma, McAdam, and Willman; 2010)

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  - balanced growth path either with labor-augmenting progress (Solow growth model) or with unitary elasticity of substitution
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- Practical considerations:
  - non-identification theorem (Diamond, McFadden, Rodriguez)
  - impose either labor-augmenting progress or $\sigma = 1$
  - impose a functional path on input-augmenting process (Klump *et al.*, 2007)
  - use dual information (cost minimization or profit maximization) short- vs. long-run elasticity of substitution

Objectives & Outline

Objectives:

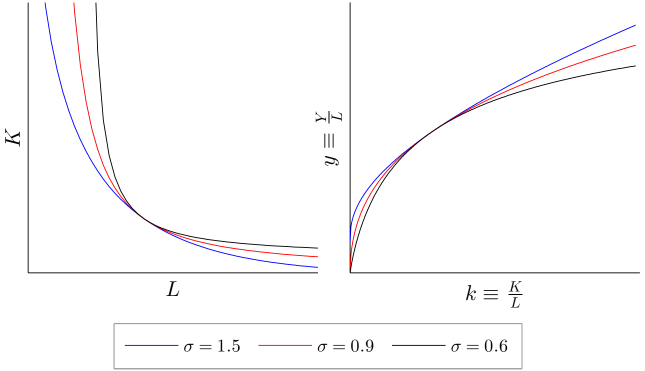
- examine the direction of technical progress (1960-2012) in 14 European economies
- provide an estimate of the elasticity of substitution between labor and capital
- test the hypothesis of price-induced innovation

Outline:

- Definitions: elasticity of substitution, input-augmenting progress, biased progress
- The non-identification theorem and panel data
- Modelling approach
- Data, results & extensions
- Conclusions

The elasticity of factor substitution

$$\sigma = \frac{\partial \log (K/L)}{\partial \log \mathrm{MRS}_{LK}} \qquad \sigma = \frac{\partial \log (k)}{\partial \log \mathrm{MRS}_{LK}}$$



Inputs are:

- *gross complements* if $\sigma < 1$
- *gross substitutes* if $\sigma > 1$

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- *factor-augmenting* if $\dot{A} > 0, \quad \dot{B} > 0$
- *Hicks neutral* if $\dot{A} = \dot{B}$, $\forall t \Rightarrow Y = C\left(t\right)F\left(K, L\right)$

Input-Biased Progress

Technical progress can be:

- Hicks neutral if the MRS_{LK} is constant (over time) along any fixed K-L ratio:

$$D\left(K, L, t\right) \equiv -\frac{\mathrm{d} \log \mathrm{MRS}_{LK}}{\mathrm{d}t} = 0$$

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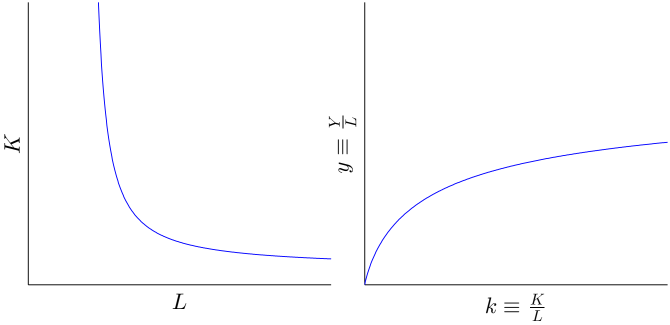
When progress is factor augmenting:

$$D\left(K,L,t\right) = \frac{\sigma - 1}{\sigma}\left[\frac{\dot{A}}{A} - \frac{\dot{B}}{B}\right]$$

Labor-Augmenting Progress with $\sigma < 1$



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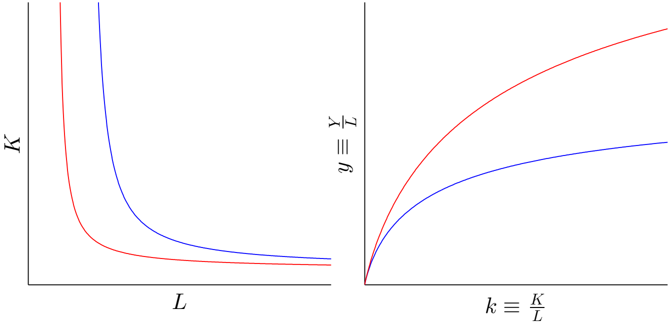

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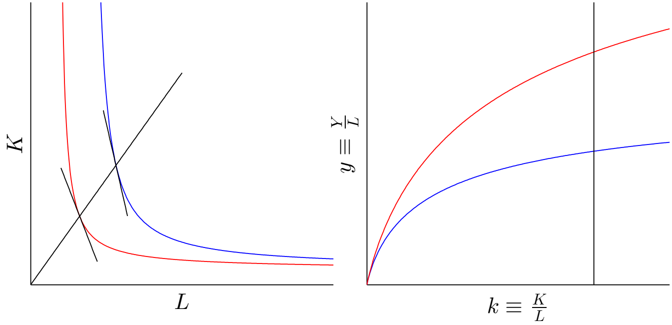

$$\frac{\mathrm{d}K}{\mathrm{d}L} \uparrow \quad \Longrightarrow \quad \mathrm{MRS}_{LK} \downarrow \quad \Longrightarrow \quad \text{labor} - \text{saving}$$

The Non-Identification Theorem

given the time series of all observable market phenomena for a single economy with classical aggregate production function, [...] the same time series could have been generated by an alternative production function having an arbitrary elasticity or bias at the observed points

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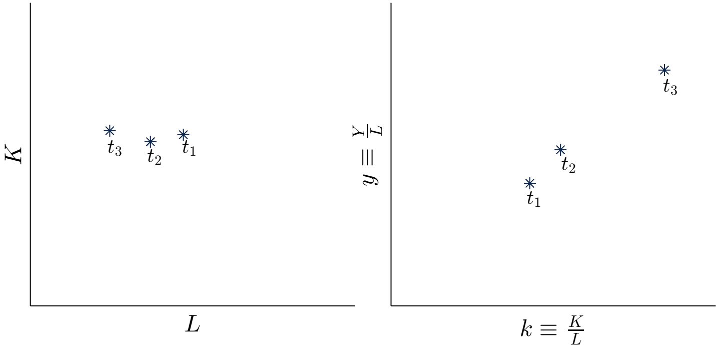

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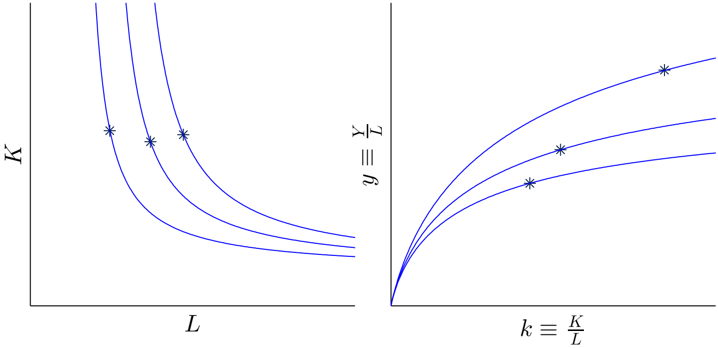

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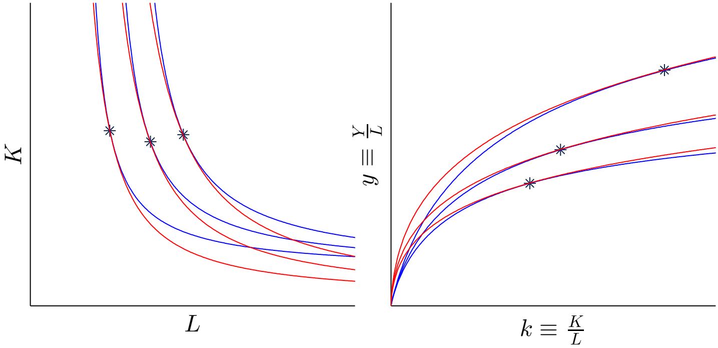

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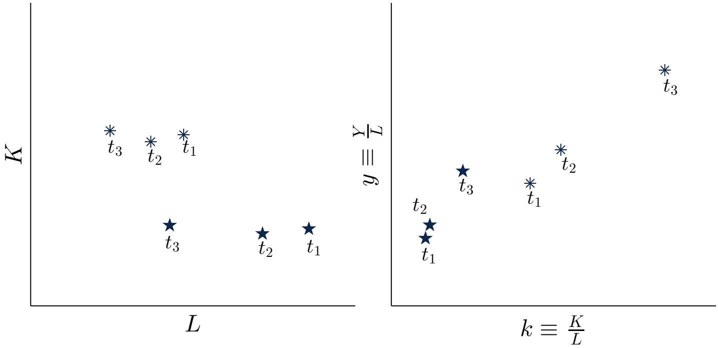

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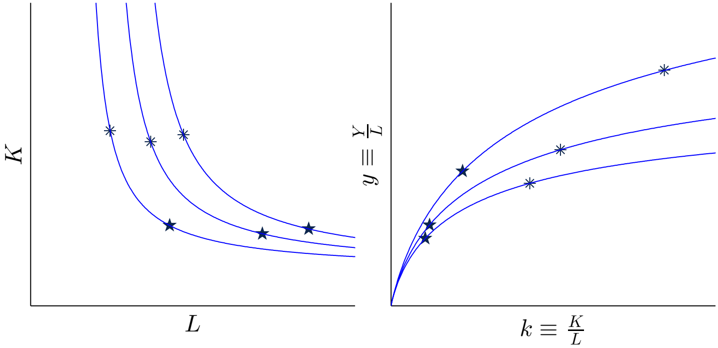

The Normalized CES Production Function

- The normalized CES production function is:

$$Y = \tilde{Y}\left[\pi\left(\frac{AK}{\tilde{K}}\right)^{\frac{\sigma-1}{\sigma}} + (1-\pi)\left(\frac{BL}{\tilde{L}}\right)^{\frac{\sigma-1}{\sigma}}\right]^{\frac{\sigma}{\sigma-1}}$$

where:

  - A and B are capital and labor efficiency indexes
  - $\tilde{K}$ is capital stock and $\tilde{L}$ labor use at the point of normalization (base period)
  - $\tilde{Y}$ is output and π is the share of capital in income at the point of normalization (base period)
  - Y, K, L, A, B implicitly depend on time

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- In per worker terms:

$$y = \tilde{y}\left[\pi\left(\frac{A}{B}\frac{k}{\tilde{k}}\right)^{\frac{\sigma-1}{\sigma}} + (1-\pi)\right]^{\frac{\sigma}{\sigma-1}}$$

  where:
  - $y = Y/L$, $\tilde{y} = \tilde{Y}/\tilde{L}$
  - $k = K/L$, $\tilde{k} = \tilde{K}/\tilde{L}$

Estimation using Dual Information

- The first-order conditions for cost minimization lead to:

$$\log(k) = \sigma \log\left(\frac{\pi}{1-\pi}\right) - (\sigma - 1)\log\left(\tilde{k}\right) + \sigma \log\left(\frac{w}{r}\right) + (\sigma - 1)\log\left(\frac{A}{B}\right)$$

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- The first-order conditions for profit maximization lead to:

$$\log\left(\frac{K}{Y}\right) = \sigma \log \pi + (\sigma-1)\log\left(\frac{\tilde{Y}}{\tilde{K}}\right) - \sigma \log(r) + (\sigma-1)\log A$$

$$\log\left(\frac{L}{Y}\right) = \sigma \log(1-\pi) + (\sigma-1)\log\left(\frac{\tilde{Y}}{\tilde{L}}\right) - \sigma \log(w) + (\sigma-1)\log B$$

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- The first-order condition for cost minimization can be written as:

$$\log(k) = \delta + \sigma \log\left(\frac{w}{r}\right) + (\sigma - 1) \cdot h(t)$$

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  - there is no way of modeling the effect of relative input prices on the process of innovation (creation or adoption)
  - in the presence of adjustment costs, σ is the short-run elasticity of substitution

Econometric Model: State-Space Formulation

- Observed equations:

$$\log k_{it} = \delta + \sigma \log\left(\frac{w_{it}}{r_{it}}\right) + (\sigma - 1)\, s_t + \varepsilon_{it}$$

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$$s_t = \zeta_1 + \zeta_2 s_{t-1} + \zeta_3 z_t + v_t$$

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- ε_{it} and v_t are white-noise error terms

Data

AMECO: Annual macro-economic database of the European Commission

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- 14 EU countries: EU-15 except Germany

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- Variables:
  - output (Y): GDP in billions of 2010 Euros
  - capital stock (K): billions of 2010 Euros
  - labor (L): thousands of persons
  - shares of inputs in GDP $\rightarrow$ input prices – w, r; using output-weighted input-price ratios

Results 1

Parameter	Mean	5%	95%
π	0.355	0.341	0.370
σ	0.901	0.866	0.936
ζ_1	-0.117	-0.263	0.006
ζ_2	0.984	0.934	1.031
σ_ε	0.180	0.173	0.189
σ_υ	0.341	0.207	0.544

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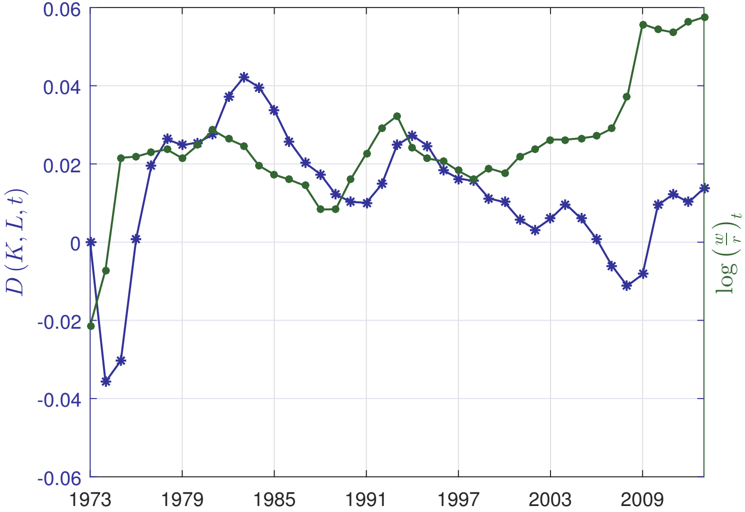
	one lag			two lags		
	Mean	5%	95%	Mean	5%	95%
π	0.360	0.345	0.375	0.361	0.346	0.376
σ	0.907	0.871	0.943	0.907	0.872	0.943
ζ_1	-0.915	-1.938	-0.049	-1.063	-2.087	-0.219
ζ_2	0.955	0.894	1.011	0.947	0.886	1.003
ζ_3	-0.466	-1.054	0.033	-0.545	-1.126	-0.065
σ_ε	0.180	0.173	0.189	0.180	0.173	0.189
σ_υ	0.357	0.210	0.584	0.348	0.205	0.570

Results 1


0.06
0.04
0.02
0
-0.02
-0.04
-0.06
1973
1979
1985
1991
1997
2003
2009
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$\log\left(\frac{w}{r}\right)_t$

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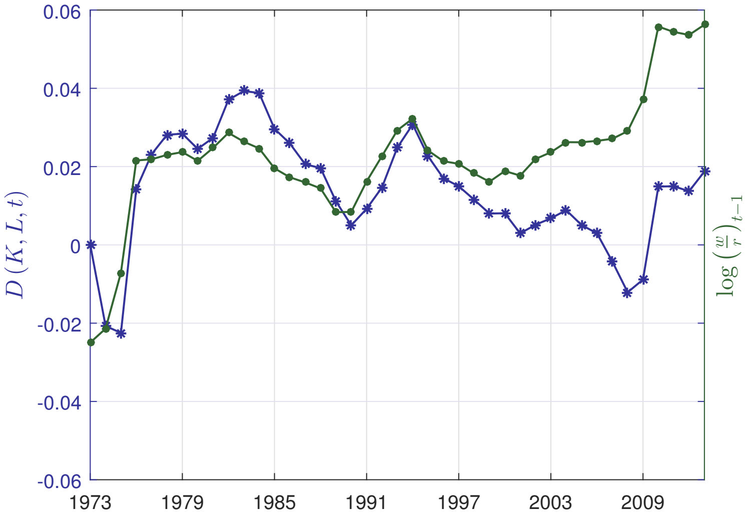
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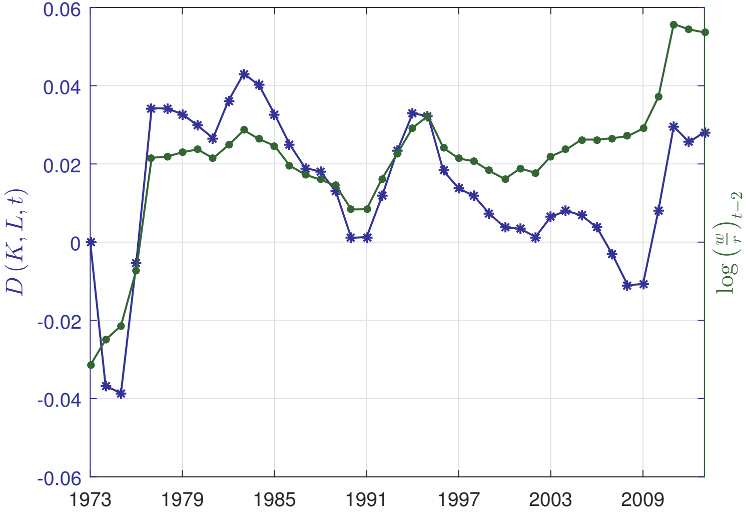
0.06
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$D(K, L, t)$
$\log\left(\frac{w}{r}\right)_{t-2}$
1973
1979
1985
1991
1997
2003
2009

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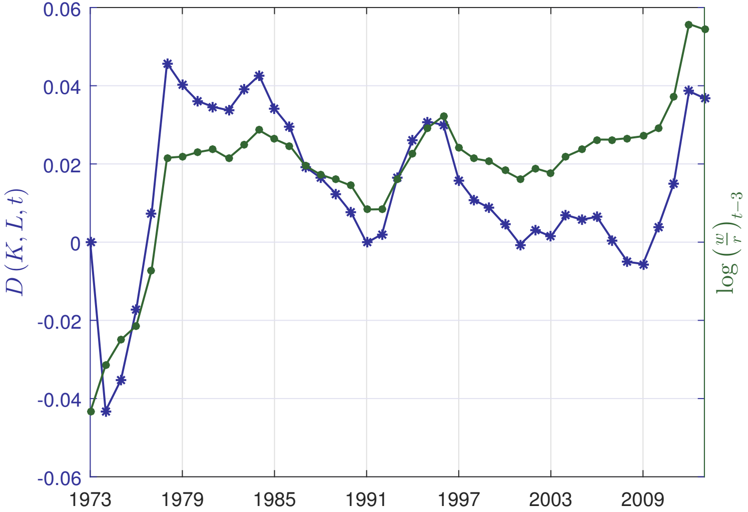
0.06
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$D(K, L, t)$
$\log\left(\frac{w}{r}\right)_{t-3}$
1973
1979
1985
1991
1997
2003
2009

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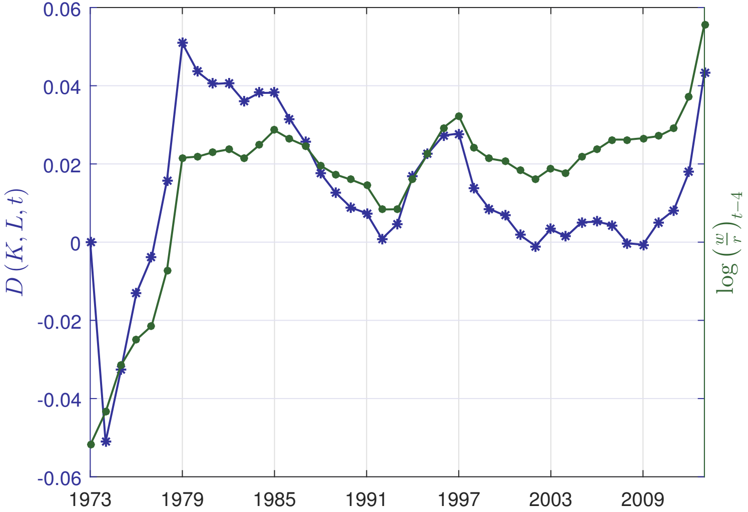
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$D(K, L, t)$
$\log\left(\frac{w}{r}\right)_{t-4}$

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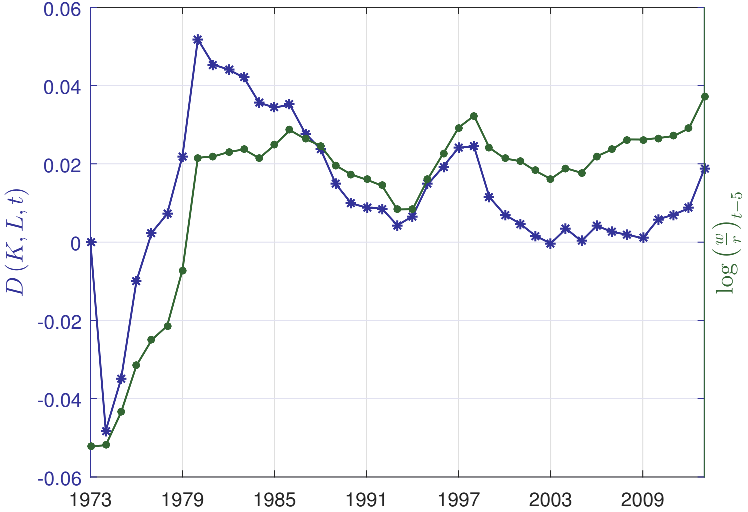
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$D(K,L,t)$
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Discussion & and Extensions

- Main findings:
  - reasonable estimate of the aggregate elasticity of substitution
  - technical progress is labor augmenting
    ($\sigma < 0 \Rightarrow$ labor saving)
  - there is large variability over time in $\frac{\dot{A}}{A} - \frac{\dot{B}}{B}$
  - relative input prices affect the direction of technical progress

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    - technical progress is labor augmenting ($\sigma < 0 \Rightarrow$ labor saving)
    - there is large variability over time in $\frac{\dot{A}}{A} - \frac{\dot{B}}{B}$
    - relative input prices affect the direction of technical progress
- Criticism:
    - the technology is the same for all countries and the relative weighted input prices drive innovation (creation & adoption)
    - allowing the direction of technical progress to be country-specific reintroduces the non-identification problem

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  - reasonable estimate of the aggregate elasticity of substitution
  - technical progress is labor augmenting ($\sigma < 0 \Rightarrow$ labor saving)
  - there is large variability over time in $\frac{\dot{A}}{A} - \frac{\dot{B}}{B}$
  - relative input prices affect the direction of technical progress
- Criticism:
  - the technology is the same for all countries and the relative weighted input prices drive innovation (creation & adoption)
  - allowing the direction of technical progress to be country-specific reintroduces the non-identification problem
- Two alternatives:
  - break the 14 Member States into homogeneous subgroups
  - allow for country-specific points of normalization

Results 2: Subgroups of Member States

	DK, FI, SE, UK		BE, FR, NL		EL, ES, IE, IT, PT	
Parameter	**Mean**	**Std. Dev.**	**Mean**	**Std. Dev.**	**Mean**	**Std. Dev.**
π	0.353	0.014	0.416	0.014	0.302	0.012
σ	0.606	0.058	0.424	0.035	0.717	0.038
ζ_1	-0.344	0.217	-0.125	0.078	-0.209	0.168
ζ_2	0.925	0.043	0.944	0.034	0.969	0.021
ζ_3	-0.162	0.118	-0.048	0.040	-0.052	0.083
σ_ε	0.100	0.005	0.054	0.003	0.112	0.006
σ_υ	0.069	0.018	0.042	0.007	0.086	0.024

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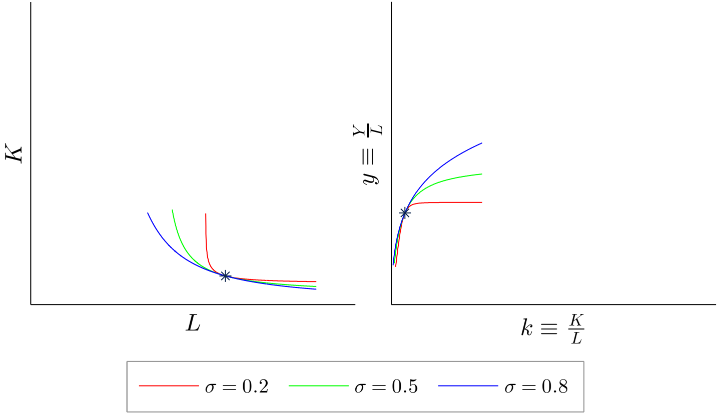

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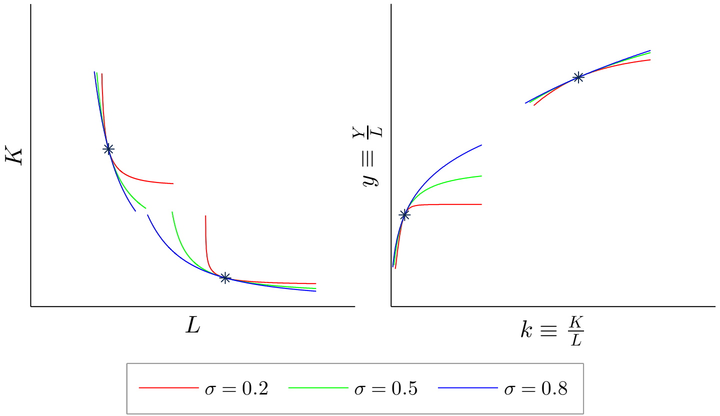

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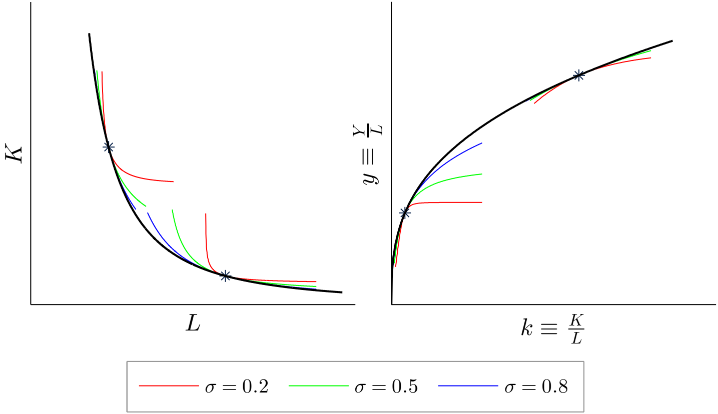

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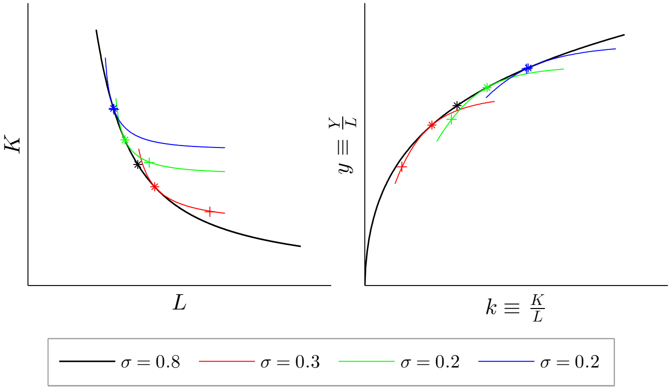
- Suggestion from literature: chose the normalization points from the data, *prior to estimation*. Instead we can estimate them
- If the global production function is Cobb-Douglas, its normalization point is irrelevant
- This is not the case when the global production function is CES with $\sigma \neq 1$



Results 3: Country-Specific Normalization Points

$$\log k_{it} = \delta + \sigma \log\left(\frac{w_{it}}{r_{it}}\right) + (\sigma - 1)\, s_t + \varepsilon_{it}$$

$$s_t = \zeta_1 + \zeta_2 s_{t-1} + \zeta_3 z_t + v_t$$

where:

$$\delta = \sigma \log\left(\frac{\pi}{1-\pi}\right) - (\sigma - 1) \log\left(\tilde{k}_i\right)$$

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	Common Normalization Point			Country-Specific Normalization Point		
Parameter	**Mean**	**5%**	**95%**	**Mean**	**5%**	**95%**
π	0.361	0.346	0.376	0.363	0.347	0.379
σ	0.907	0.872	0.943	0.692	0.666	0.718
ζ_1	-1.063	-2.087	-0.219	-0.312	-0.563	-0.076
ζ_2	0.947	0.886	1.003	0.950	0.902	0.994
ζ_3	-0.545	-1.126	-0.065	-0.141	-0.276	-0.014
σ_ε	0.180	0.173	0.189	0.147	0.141	0.154
σ_υ	0.348	0.205	0.570	0.078	0.054	0.108

Discussion & Conclusions

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    - reasonable estimates of the elasticity of substitution
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- A step forward towards identifying the elasticity of substitution with panel data:
  - reasonable estimates of the elasticity of substitution
  - relative input prices affect the direction of technical progress
- Criticism:
  - the composition of the labor force has changed over the period of analysis; manifested as labor augmentation
  - the price of capital was imputed from the share of capital and capital stock – no markup