Does automation erode governments' tax basis?

An empirical assessment of tax revenues in Europe

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Outline

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Really?

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Today: Technology has changed

Many of the tasks executed by humans at work can now be done by machines.

In this paper, we ask:

What happens to taxes when automation technologies diffuse?

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Opinions of others

Robots replace jobs and undermine the tax basis

Should mass workplaces for humans disappear in the future, from a tax perspective a double negative effect could occur. On the one hand, significant tax and social security revenues would be lost, while on the other hand, the need would increase for additional state revenue to support the growing number of unemployed human workers.

Xavier Oberson 2017: "How Taxing Robots Could Help Bridge Future Revenue Gaps"

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Others contradict

> *"Help!" they cry, "Robots are coming for our jobs!" [...] The biggest mistake "robophobes" make when they predict higher unemployment is to omit second-order effects*

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They claim: Concerns about undermined tax basis for no reason.

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Our research aim

Check the empirical validity of these claims!

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What happens to the economy if automation diffuses?

Replacement

- Replacement of human labor by machines:
  - Negative effect on labor demand in industries where AT diffuses.
  - Ambiguous effect on wages: Negative if substituting, positive if complementing.

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Reinstatement

- Creation of new tasks/ occupations in (1) AT-adopting and (2) other industries triggered by efficiency gains :
  - Reallocation of labor within and across industries.
  - Positive effect on aggregate employment.

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Real-income

- Composite effect arising from changing price levels and factor incomes:
  - Productivity $\uparrow \quad \rightarrow$ prices for final goods $\downarrow$ s.t. market competition.
  - Aggregate factor revenues from capital and labor change.
  - Aggregate demand increases if positive real-income effect.

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AT diffusion and taxation

Existing literature

- Optimal taxation wrt. robot adoption:
  - Mostly theoretical: Study (welfare) effects of existing tax systems on AT adoption and emerging patterns of techn. change.
  - Distorted tax system in favor of capital as driver of "excessive automation".
- Robot tax literature:
  Tax on robots to cope with:
  - Inequality, excessive automation/ existing distortions, raise public revenues.

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Our contribution

Opposite perspective: Taking AT adoption decisions as given,

What is the effect of AT on taxation?

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3 research questions:

1. *What is the effect of AT diffusion on aggregate tax revenues at the country level in absolute terms and in relation to GDP?*
2. *What is the effect of AT diffusion on the composition of taxes by source distinguishing between taxes on labor, capital and goods?*
3. *How can these effects be traced back to the three effects through which AT impacts the structure and level of economic production?*

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The empirical reality of taxation

Composition of taxation in Europe in 2016

- Taxes raised from different sources:
  - Labor (31.6%),
  - capital (35.1%),
  - sales (32.5%).[1]
- Total tax revenue := 37.3% of GDP.

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[1] Numbers indicate share in total taxation. Data for 19 EU countries in 2016.

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Complexity as empirical challenge

- Aggregate accounts are composites of various sources (property, inheritance, SSC, wages, etc.) with different accounting standards across countries.
- Non-linearities arising from thresholds and exemptions.
- Countries differ by tax administration: local, federal, central government.

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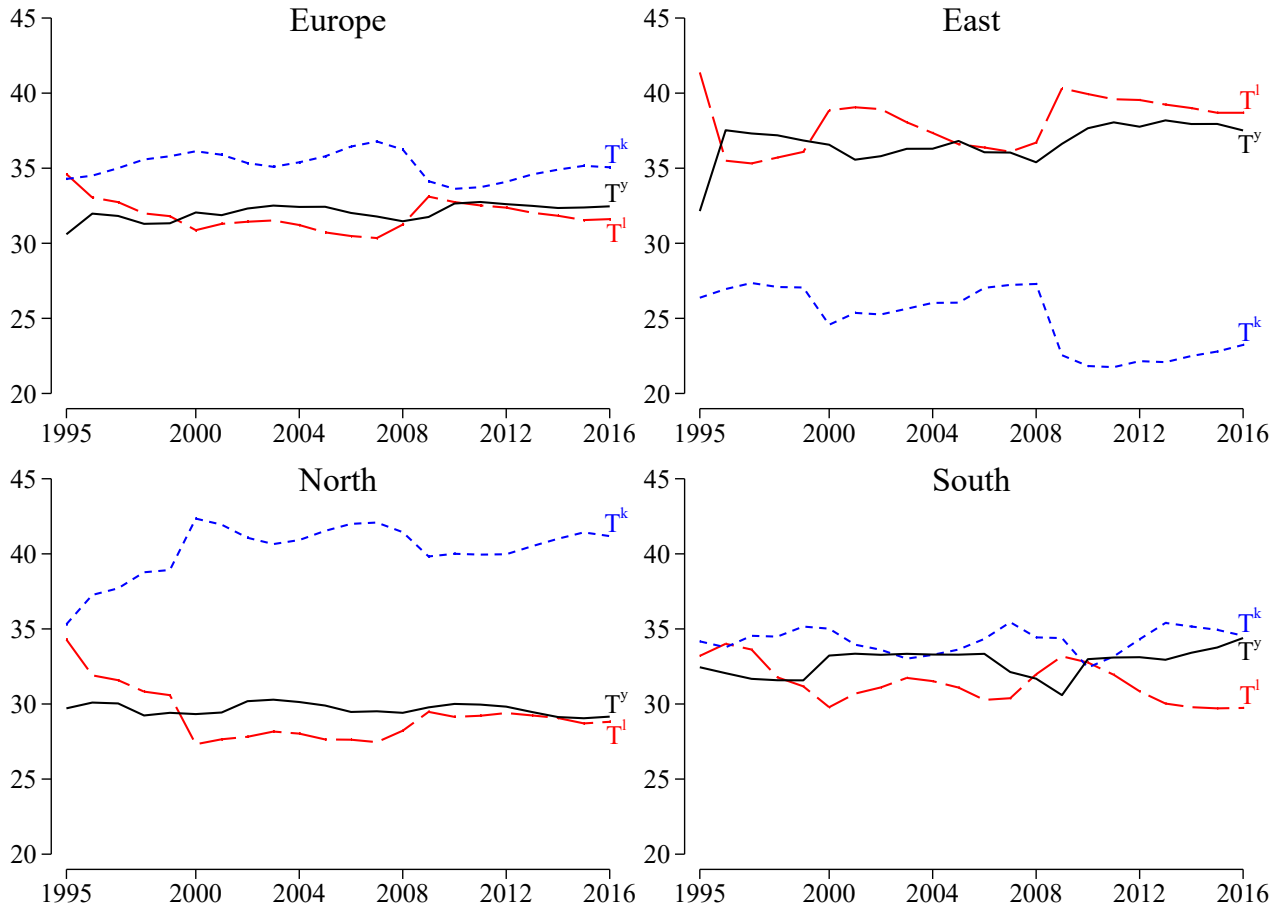
Structure of taxation in different EU countries



The structure of taxation is measured as taxes on different sources (labor T^l, capital T^k, goods T^y) as percentage share in total taxation. The subsets of Eastern, Northern and Southern European countries are defined as follows: East: CZ; LT; LV; SI; and SK. North: AT; BE; DE; DK; FI; FR; IE; NL; SE; and UK. South: ES; GR; IT; and PT.

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A stylized model of taxation

Total tax revenue in country c:

$$T_c = \underbrace{t_c^l \cdot w_c L_c}_{\substack{\text{Taxes on labor} \\ T_c^l}} + \underbrace{t_c^k \cdot r_c K_c}_{\substack{\text{Taxes on capital} \\ T_c^k}} + \underbrace{t_c^y \cdot p_c Q_c}_{\substack{\text{Taxes on goods} \\ T_c^y}} \quad (1)$$

with:

- $L_c = \sum_{i \in I_c} L_i$: aggr. labor as sum of labor in industries $i \in I_c$ in c,
- $K_c = \sum_{i \in I_c} K_i$: aggr. capital stock incl. AT tech (i.e. robots & ICT),
- $p_c Q_c = \sum_{i \in I_c} p_i Q_i$: aggr. demand,
- w_c, r_c and p_c: Wages, prices for capital and goods.

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Production at the micro-level

Industry-level production function in a generic form:

$$y_i = f_i(K_i, L_i, A_i) \tag{2}$$

with:

- K_i and L_i as capital and labor,
- $K_i = K_i^n + K_i^a$ with K_i^n as non-AT and $K_i^a = ICT_i + R_i$ as AT capital, R_i as industrial robots and ICT_i as ICT.

We assume:

- $\frac{\partial f_i}{\partial L_i} \geq 0$, $\frac{\partial f_i}{\partial K_i} \geq 0$, $\frac{\partial f_i}{\partial A_i} \geq 0$,
- $\frac{\partial L_i}{\partial w_i} \leq 0$ and $\frac{\partial K_i}{\partial r_i} \leq 0$.
- Note: Assumptions may not hold due to composition effects.

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The effects of AT diffusion

$$dT_c = t_c^l \cdot \left(\frac{\partial w_c}{\partial K_c^a} L_c + w_c \frac{\partial L_c}{\partial K_c^a} \right) + t_c^k \cdot \left(\frac{\partial r_c}{\partial K_c^a} K_c + r_c \frac{\partial K_c}{\partial K_c^a} \right)$$

$$+ t^Y \cdot \left(\frac{\partial P_c}{\partial K_c^a} Q_c + P_c \frac{\partial Q_c}{\partial K_c^a} \right) \tag{3}$$

with $K_c^a = R_c + ICT_c$, $R_c = \sum_{i \in I_c} R_i$ and $ICT_c = \sum_{i \in I_c} ICT_i$.

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with $K_c^a = R_c + ICT_c$, $R_c = \sum_{i \in I_c} R_i$ and $ICT_c = \sum_{i \in I_c} ICT_i$.

3 effects of AT diffusion:

1. Replacement: $\frac{\partial L_i}{\partial K_i^a} < 0$ & $\frac{\partial w_i}{\partial K_i^a} \leqslant 0$ for $i \in \{j | K_j^a > 0\}$,
2. Reinstatement: $\frac{\partial L_i}{\partial K_i^a} > 0, i \in \{j | K_j^a > 0\}$ & $\frac{L_c}{\partial K_c^a} > 0$; $\frac{\partial w_c L_c}{\partial K_c^a} > 0$,
3. Real-income: $\frac{\partial (w_c L_c + r_c K_c)}{\partial K_c^a} \leqslant 0$ & $\frac{\partial p_i}{\partial K_i^a} \leq 0$.

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Empirical strategy

Major challenge

- Complexity of taxation: Macro-level tax rates t^l, t^k, t^y do not exist.
- Industry- or firm-level data on taxation is non-existent or partial & 2nd order effects require macroeconomic approach.

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Solution

Step-wise procedure:

1. Establish link between aggregate tax data and economic production.
2. Test for the 3 effects of AT diffusion.
3. Explain aggregate observations wrt taxation along the 3 effects.

Analysis at the industry- and country-level.

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Data

- Tax data from OECD Global Revenue Statistics Database:
  - $T^{l}_{c,t}$: *SSC (2000) + Taxes on payroll (3000)*;
  - $T^{k}_{c,t}$: *Taxes on income, profits, capital gains (1000) + on property (4000)*;
  - $T^{y}_{c,t}$: *Taxes on goods and services (5000)*.

  Data in levels, pct. GDP, pct. share in total taxation.

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  Data in levels, pct. GDP, pct. share in total taxation.
- Economic data from EUKLEMS:
  - $w_{c,t}L_{c,t} = \sum_{i \in I_c} w_{i,t}L_{i,t}$ as labor compensation;
  - $r_{c,t}K_{c,t} = \sum_{i \in I_c} r_{i,t}K_{i,t}$ as capital compensation;
  - and *GO* for $p_{c,t}Q_{c,t} = \sum_{i \in I_c} p_{i,t}Q_{i,t}$ as gross output;
  - $w_{i,t}$, $r_{i,t}$ and $p_{i,t}$ calculated by dividing values by volumes.

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  - $w_{i,t}$, $r_{i,t}$ and $p_{i,t}$ calculated by dividing values by volumes.
- Additionally:
  - Industrial restructuring: HHI_c & employment/output share of services.
  - Exchange rate, debt, interest, public investm., net lending.

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Measuring AT diffusion

2 types of automation technologies

1. Industrial robots: Designed to automate clearly defined manual tasks.
2. ICT: Substituting and/or complementing (often less well defined) cognitive tasks.
3. Simultaneous diffusion as "depth of automation": Automate manual and cognitive tasks.

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Empirical proxies

- Robots: $R_{c,t} = \frac{\sum_{i \in I_c} \#Robots_{i,t}}{\sum_{i \in I_c} L_{i,t}}$ with robot-count data from IFR.
- ICT: Net ICT capital (by EUKLEMS) per $L_{i,t}$.

Both measures Z-score normalized.

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Establishing prerequisites:

1: Taxation and AT diffusion

$$\Theta \sim \beta_c^R R_{c,t} + \beta_c^{ICT} ICT_{c,t} + \beta_c^{RICTint} R_{c,t} \cdot ICT_{c,t} + \beta_c^z Z_{c,t} + \epsilon_{c,t} \quad (4)$$

where $\Theta \in \{T_{c,t}, T^l_{c,t}, T^k_{c,t}, T^y_{c,t}\}$ in levels, pct GDP, pct total taxation. Control for country and time FE and a series of macro controls $Z_{c,t}$.

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2: Determinants of taxation

Same regression, but now focus on macroeconomic determinants of taxation.

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Prerequisites 1: Taxation and AT diffusion (1995-2016)

	Taxes in ln of nat. currency				Taxes as % of GDP				Taxes as % of total tax		
	ln $T_{c,t}$	ln $T^l_{c,t}$	ln $T^k_{c,t}$	ln $T^y_{c,t}$	$T_{c,t}$	$T^l_{c,t}$	$T^k_{c,t}$	$T^y_{c,t}$	$T^l_{c,t}$	$T^k_{c,t}$	$T^y_{c,t}$
Panel A: full period 1995-2016											
$R_{c,t}$	-0.019*	-0.039*	0.013	-0.014	-0.056	-0.323	0.322	-0.055	-0.922	0.801	-0.202
	(0.010)	(0.019)	(0.040)	(0.021)	(0.421)	(0.226)	(0.357)	(0.127)	(0.598)	(0.905)	(0.515)
$ICT_{c,t}$	-0.061***	-0.093	-0.122***	-0.047*	-1.620***	0.022	-1.794**	0.152	1.291	-2.695**	1.457**
	(0.011)	(0.095)	(0.038)	(0.024)	(0.544)	(0.353)	(0.641)	(0.165)	(0.903)	(1.118)	(0.608)
$R * ICT_{c,t}$	0.022***	0.022	0.048**	0.031**	0.429	-0.199	0.589**	0.040	-0.893**	1.067**	-0.196
	(0.005)	(0.034)	(0.017)	(0.012)	(0.290)	(0.153)	(0.269)	(0.077)	(0.363)	(0.429)	(0.291)
R^2	0.999	.998	.999	.999	.973	.985	.975	.96	.983	.972	.956
N	395	395	395	395	395	395	395	395	395	395	395
Panel B: sub-period 1995-2007											
$R_{c,t}$	-0.040*	-0.078	-0.108***	0.020	-0.683*	-0.223	-0.830**	0.370**	-0.104	-1.984**	1.315**
	(0.021)	(0.049)	(0.031)	(0.032)	(0.382)	(0.185)	(0.377)	(0.132)	(0.480)	(0.730)	(0.459)
$ICT_{c,t}$	-0.042	-0.163	-0.110*	-0.008	-0.856	0.275	-1.269	0.138	0.967	-2.616	0.873
	(0.027)	(0.123)	(0.057)	(0.028)	(0.701)	(0.468)	(0.760)	(0.187)	(1.024)	(1.510)	(0.997)
$R * ICT_{c,t}$	0.008	0.036	0.019	0.000	0.083	0.053	-0.025	0.054	0.254	0.170	0.107
	(0.017)	(0.045)	(0.031)	(0.016)	(0.567)	(0.267)	(0.415)	(0.092)	(0.423)	(0.681)	(0.624)
R^2	0.999	.998	.999	0.999	.982	.988	.984	.972	.99	.986	.969
N	224	224	224	224	224	224	224	224	224	224	224
Panel C: sub-period 2008-2016											
$R_{c,t}$	-0.012	0.015	0.016	-0.058	0.210	0.233	0.196	-0.220	0.479	0.439	-0.901
	(0.023)	(0.025)	(0.059)	(0.034)	(0.758)	(0.405)	(0.539)	(0.238)	(0.925)	(0.956)	(0.776)
$ICT_{c,t}$	0.019	-0.007	0.017	0.026	0.280	-0.118	0.137	0.261***	-1.274	0.519	0.731
	(0.036)	(0.050)	(0.034)	(0.056)	(0.466)	(0.623)	(0.318)	(0.058)	(1.056)	(0.753)	(0.657)
$R * ICT_{c,t}$	-0.020	-0.000	-0.016	-0.035	-0.149	-0.131	0.098	-0.117	0.399	-0.302	-0.135
	(0.024)	(0.031)	(0.039)	(0.033)	(0.647)	(0.376)	(0.605)	(0.095)	(0.595)	(0.736)	(0.535)
R^2	0.999	0.999	.999	0.999	.986	.994	.989	.984	.992	.989	.982
N	171	171	171	171	171	171	171	171	171	171	171

Findings:

Negative impact of AT on total tax revenues, ICT (robots) at cost of capital (labor) taxes.

Relative shares of other tax sources weakly increased.

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Prerequisites 2: The determinants of taxation

Main observations:

- Taxes in levels:
  - Robots: Total and labor taxes ↓
  - ICT: Total and capital taxes ↓
  - Depth of automation (ICT & Robots): moderating effect on total, capital and taxes on goods
- Taxes in pct. GDP:
  - Robots: no strong shifts in the structure
  - ICT: total and capital tax share ↓, weak effects on other factor shares

Other findings:

- Indebted countries tend to raise more tax revenues.

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Replacement effect

	ln $wL_{i,c,t}$	ln $w_{i,c,t}$	ln $L_{i,c,t}$	ln $rK_{i,c,t}$	ln $r_{i,c,t}$	ln $K_{i,c,t}$
Panel A: full period 1995-2016						
$R_{i,c,t}$	-0.031	0.026**	-0.057**	-0.053	-0.011	0.008
	(0.031)	(0.010)	(0.027)	(0.036)	(0.007)	(0.027)
$ICT_{i,c,t}$	0.020	0.005	0.015	0.026	-0.001	0.028
	(0.012)	(0.005)	(0.013)	(0.026)	(0.010)	(0.023)
$R * ICT_{i,c,t}$	-0.007	0.005**	-0.012**	0.003	-0.004	0.006
	(0.005)	(0.002)	(0.005)	(0.009)	(0.002)	(0.007)
R^2	.997	.996	.994	.972	.927	.996
N	4898	4898	4898	4843	4803	4803
Panel B: sub-period 1995-2007						
$R_{i,c,t}$	-0.006	0.016*	-0.022	0.005	-0.002	0.020
	(0.028)	(0.008)	(0.027)	(0.050)	(0.005)	(0.021)
$ICT_{i,c,t}$	0.026**	0.005	0.021*	0.001	0.001	0.029
	(0.010)	(0.005)	(0.010)	(0.027)	(0.010)	(0.017)
$R * ICT_{i,c,t}$	0.002	0.001	0.001	-0.003	-0.000	0.008
	(0.005)	(0.002)	(0.005)	(0.015)	(0.003)	(0.008)
R^2	.998	.997	.996	.975	.94	.998
N	2827	2827	2827	2790	2777	2777
Panel C: sub-period 2008-2016						
$R_{i,c,t}$	-0.034	0.013	-0.047*	-0.021	-0.004	-0.021
	(0.027)	(0.012)	(0.023)	(0.043)	(0.004)	(0.020)
$ICT_{i,c,t}$	-0.033	0.016	-0.049	-0.100	-0.006	-0.036
	(0.027)	(0.010)	(0.027)	(0.095)	(0.005)	(0.053)
$R * ICT_{i,c,t}$	-0.012	0.000	-0.012	0.028	-0.003*	0.011
	(0.010)	(0.004)	(0.009)	(0.020)	(0.002)	(0.009)
R^2	.999	.998	.998	.985	.918	.999
N	2070	2070	2070	2052	2025	2025

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Reinstatement effect

	ln $w_{c,t}$	ln $L_{c,t}$	ln $r_{c,t}$	ln $K_{c,t}$	$Services_{c,t}$	$Gini^{w}_{c,t}$
Panel A: full period 1995-2016						
$R_{c,t}$	-0.128***	-0.006	-0.088***	-0.056**	-0.941***	0.032***
	(0.032)	(0.016)	(0.031)	(0.026)	(0.269)	(0.009)
$ICT_{c,t}$	0.168***	-0.092**	0.077	-0.006	0.527	0.038***
	(0.049)	(0.040)	(0.047)	(0.069)	(1.008)	(0.013)
$R * ICT_{c,t}$	-0.075***	0.035**	-0.032	-0.004	0.212	-0.008
	(0.023)	(0.016)	(0.022)	(0.037)	(0.464)	(0.006)
R^2	.995	.999	.907	.999	.973	.762
N	395	395	395	395	395	395
Panel B: sub-period 1995-2007						
$R_{c,t}$	-0.145***	-0.040	-0.084**	-0.065**	-1.539***	0.011
	(0.040)	(0.023)	(0.029)	(0.026)	(0.497)	(0.011)
$ICT_{c,t}$	0.301***	-0.142***	0.141***	-0.049*	-2.427**	0.018
	(0.052)	(0.023)	(0.040)	(0.024)	(1.107)	(0.017)
$R * ICT_{c,t}$	-0.141***	0.040***	-0.065**	0.017	1.215*	-0.006
	(0.032)	(0.011)	(0.023)	(0.015)	(0.607)	(0.010)
R^2	.998	.999	.923	0.999	.98	.878
N	224	224	224	224	224	224
Panel C: sub-period 2008-2016						
$R_{c,t}$	-0.034	0.018	-0.039	-0.004	-1.635**	0.009*
	(0.027)	(0.019)	(0.028)	(0.023)	(0.562)	(0.004)
$ICT_{c,t}$	0.011	0.008	0.046	0.100*	2.054	0.006
	(0.018)	(0.035)	(0.036)	(0.047)	(1.161)	(0.007)
$R * ICT_{c,t}$	-0.032**	0.002	-0.036	-0.038	-0.467	0.008
	(0.013)	(0.021)	(0.024)	(0.034)	(0.726)	(0.005)
R^2	.999	0.999	.822	0.999	.988	.948
N	171	171	171	171	171	171

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Real-income effect

	ln $wL_{c,t}$	ln $rK_{c,t}$	ln $(wL+rK)_{c,t}$	ln $pQ_{c,t}$	ln $Q_{c,t}$	ln $p_{c,t}$	ln $LProd_{c,t}$	ln $TFP_{c,t}$
Panel A: full period 1995-2016								
$R_{c,t}$	-0.131***	-0.133**	-0.139***	-0.113**	0.009	-0.099***	-0.006	-0.004
	(0.039)	(0.047)	(0.042)	(0.040)	(0.029)	(0.029)	(0.019)	(0.014)
$ICT_{c,t}$	0.068	-0.062	0.015	0.017	0.026	-0.019	0.093**	-0.046
	(0.057)	(0.058)	(0.055)	(0.049)	(0.032)	(0.044)	(0.033)	(0.030)
$R * ICT_{c,t}$	-0.033	0.005	-0.019	-0.026	-0.016	0.016	-0.049**	0.027**
	(0.036)	(0.035)	(0.036)	(0.035)	(0.026)	(0.021)	(0.022)	(0.012)
R^2	.997	.996	.997	.997	.999	.916	.998	.869
N	395	395	395	395	309	309	309	309
Panel B: sub-period 1995-2007								
$R_{c,t}$	-0.193***	-0.147***	-0.180***	-0.133***	-0.060***	-0.114***	-0.017	0.009
	(0.038)	(0.041)	(0.037)	(0.038)	(0.015)	(0.023)	(0.011)	(0.011)
$ICT_{c,t}$	0.126***	-0.034	0.059	0.096*	0.015	0.014	0.142***	-0.091***
	(0.040)	(0.066)	(0.049)	(0.054)	(0.018)	(0.047)	(0.031)	(0.028)
$R * ICT_{c,t}$	-0.074**	-0.048	-0.060*	-0.085**	-0.010	-0.015	-0.061**	0.058***
	(0.028)	(0.038)	(0.032)	(0.035)	(0.015)	(0.027)	(0.020)	(0.015)
R^2	.999	.998	.999	.999	0.999	.946	.999	.929
N	224	224	224	224	174	174	174	174
Panel C: sub-period 2008-2016								
$R_{c,t}$	-0.008	-0.035	-0.025	-0.006	0.066**	-0.033**	0.028	-0.003
	(0.030)	(0.039)	(0.024)	(0.025)	(0.026)	(0.014)	(0.026)	(0.010)
$ICT_{c,t}$	0.047	0.127*	0.083*	0.069	0.039	0.029	0.013	0.020***
	(0.034)	(0.061)	(0.037)	(0.054)	(0.029)	(0.020)	(0.022)	(0.002)
$R * ICT_{c,t}$	-0.029	-0.063	-0.048	-0.049	-0.018	-0.026*	-0.016	-0.002
	(0.030)	(0.040)	(0.029)	(0.035)	(0.026)	(0.013)	(0.019)	(0.009)
R^2	.999	.999	0.999	0.999	0.999	.875	0.999	.978
N	171	171	171	171	135	135	135	135

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Key observations:

Replacement (industry level)

- Robots & depth of adoption: Labor $\downarrow$, wages $\uparrow$.
- ICT: No effect on wages or Labor.

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Key observations:

Replacement (industry level)

- Robots & depth of adoption: Labor ↓, wages ↑.
- ICT: No effect on wages or Labor.

Reinstatement (country level)

- Robots: Wages ↓
- ICT & depth of automation: Wages ↑, Labor ↓

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Key observations:

Replacement (industry level)

- Robots & depth of adoption: Labor ↓, wages ↑.
- ICT: No effect on wages or Labor.

Reinstatement (country level)

- Robots: Wages ↓
- ICT & depth of automation: Wages ↑, Labor ↓

Real-income (country level)

- Robots: factor incomes (K,L,Q) and Prices ↓
- ICT: factor incomes (K,L,Q) no effect. Labor productivity ↑; .
- In total: Labor replacing tech without efficiency gains ↓ on taxes and incomes
  Labor augmenting tech with efficiency gains ↓ on taxes but ↑ productivity

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Robustness checks

Subnational results

- Country-level ATs used for NUTS0, NUTS2 and NUTS3 regions.
- Germany and the UK: Some regions exhibit strong negative, others strong positive impacts across ATs
- Spain, France and the Baltic countries are the beneficiaries of automation: Both, robots and ICT diffusion, exhibit positive effects on regional labor demand and corporate taxation.
- Sweden and Finland, have negative effects of robot diffusion on both, labor and taxes, and mixed effects of ICT.
- Contradicting effects for Italy and Greece across ATs: robots have a positive impact on labor and taxation in Italy, but we find a negative impact of ICT. The opposite pattern holds true for parts of Greece where ICT tends to exhibit a positive effect, but robots a negative one.

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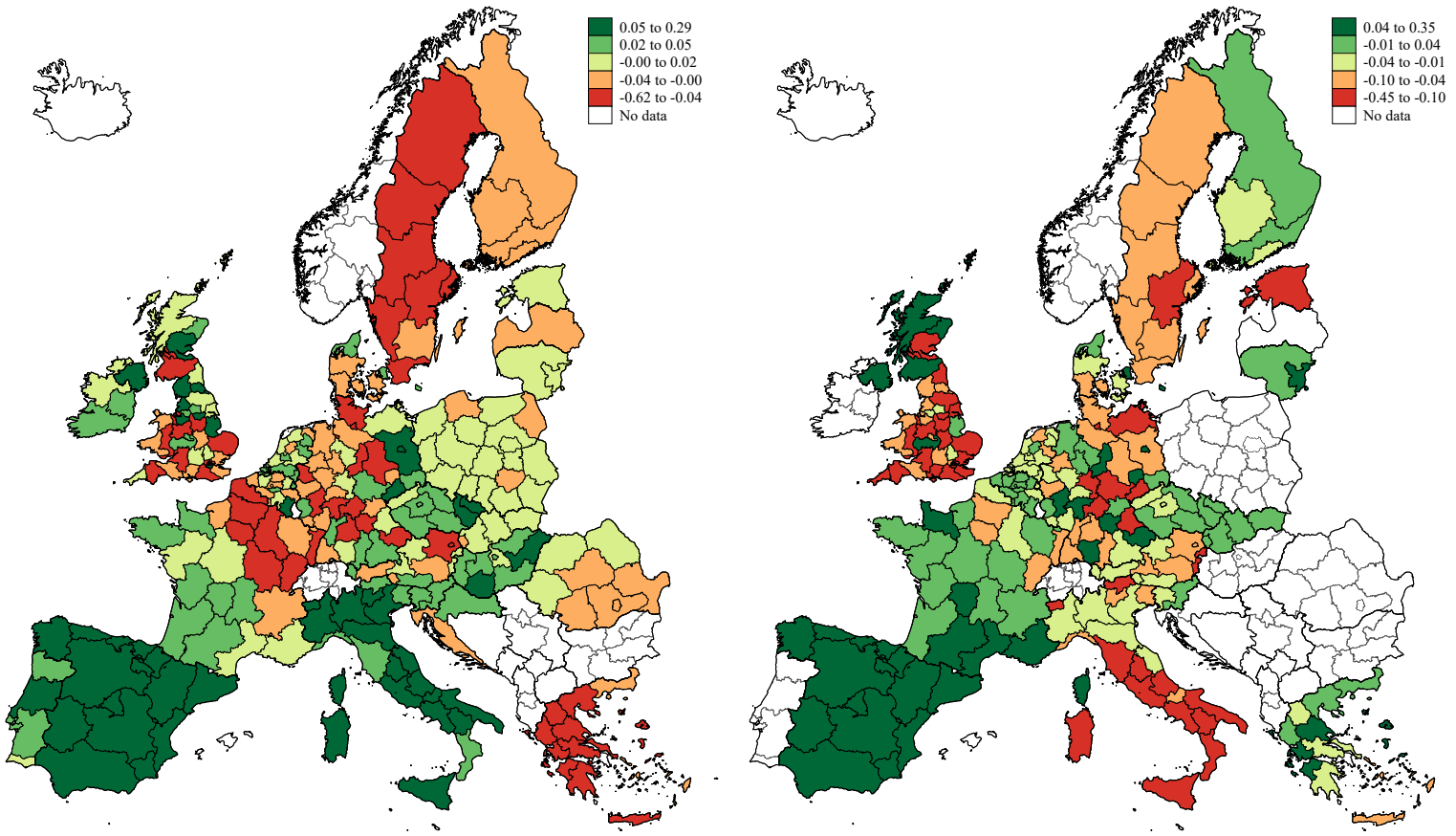

(a) Robots (b) ICT

Abbildung: Robots & ICT effects on Labor.

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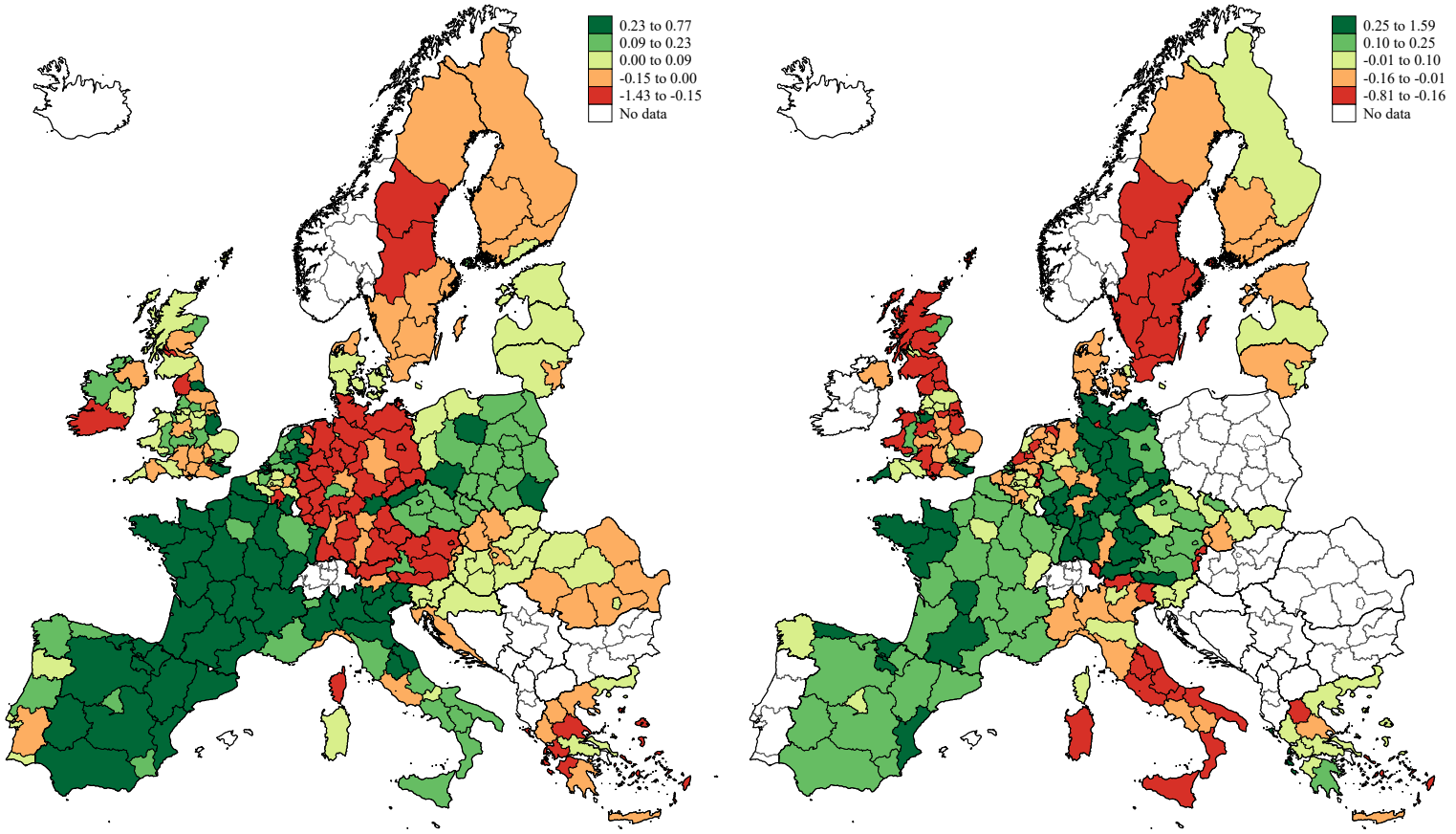

(a) Robots (b) ICT

Abbildung: Robots & ICT effects on Taxes.

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Robustness checks

Endogeneity

- 2 types of lagged data on robot- and ICT-intensity from $t-1$ instead of contemporaneous diffusion measures as explanatory variable. Deeper lags from $t-1$, $t-2$ and $t-3$ are used as explanatory variables on the first stage to instrument contemporaneous AT diffusion.
- IVs: AT imports to other countries driven by technological advances in ATs, but are entirely exogenous from the economic dynamics in country c. For this we use robot and ICT products imports by all countries in the world except c as in instrument for robot and ICT diffusion in country c.
- We obtain qualitatively consistent point estimates for the coefficients

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Robustness checks

Further tests

- Sensitivity to changes in tax systems:
  - KPMG data on country level tax rates (additional controls on tax regressions)
  - Effective tax rates (ETR) by Eurostat for non-financial corporations
- Trade: Include imports ($Imports_{c,t}^{\%GDP}$) and exports ($Exports_{c,t}^{\%GDP}$) as percentage of GDP (OECD) (on top of exchange rates already included)
- Distributional effects:
  - Gini coefficients from industry level distribution of hourly wage ($Gini_{c,t}^{w}$) and labor in terms of hours worked ($Gini_{c,t}^{L}$)
  - dispersion measures computed as the 90/10 percentile ratio from the industry level distribution of hourly wage ($Dispersion_{c,t}^{w}$) and labor in terms of hours worked ($Dispersion_{c,t}^{L}$) (EUKLEMS).
- Tax progressiveness: tax regressions with the Gini coefficient from industry level distribution of labor in terms of hours worked ($Gini_{c,t}^{L}$).

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3 questions - 3 answers

1. *What is the effect of AT diffusion on aggregate tax revenues at the country level in levels and in relation to GDP?*
   - Theory: Dependent on income effects of AT: If negative $\rightarrow$ taxes $\downarrow$
   - We observed: Negative impact of robots and ICT (esp. $\leq$ 2007)
   - Taxes in $\%GDP$ more stable, but negatively dep. on factor income affected, i.e. $\downarrow$ in labor for Robots, $\downarrow$ in capital for ICT.

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3 questions - 3 answers

2. *What is the effect of AT diffusion on the composition of tax revenues by source distinguishing between taxes on labor, capital and goods?*

- We observed:
  - Robots: Weak shift from taxes on labor to taxes capital (likely policy response).
  - ICT: Strong shift from taxes on capital to labor and goods.

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3 questions - 3 answers

3. *How can these effects be traced back to the three effects through which AT affects the structure and level of economic production?*

- Robots: Labor-replacing tech without clear efficiency gains. All factor incomes $\downarrow$ and so do the levels of taxes. Support for so-so automation hypothesis and tax distortions towards capital. Policy response weakly altered these effects.
- ICT: Labor-augmenting tech with efficiency gains (productivity $\uparrow$). ICTs erode tangible capital (and its taxes) without any factor income affected. Support for the effects of intangible transition $\approx$ creative destruction and potentially some profit shifting of intangibles.

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Limitations and open issues

Limitations & (potential) ways forward:

- Tax burdens unequally distributed: The poor pay less taxes on labor and more on goods.
- Tax micro-data for firms, industries
- Missing work on large MNEs for Base Erosion and Profit Shifting (BEPS) across the sample

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Final Remark

- Sustainability of public finances affected when technologies are labor or capital replacing. Demographics, skills, mobility and competitive landscape need to be the focus of governments.
- If ICTs evolve in a similar manner to Robots (through AI) public finances will be affected further (beyond the capital effects already observed).
- Beyond labor substitution, these are tough times for tax policies with ICT acceleration and remote work ↑. Harder to draw regional boundaries of labor and (intangible) capital.
- Reallocation policies of AT benefits should be considered as an integral part of the EU digital agenda.

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Conclusion

Thank you for attending.

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Prerequisites 1: Taxation and AT diffusion North (1995-2016)

	Taxes in ln of nat. currency				Taxes as % of GDP				Taxes as % of total tax		
	$lnT_{c,t}$	$lnT^l_{c,t}$	$lnT^k_{c,t}$	$lnT^y_{c,t}$	$T_{c,t}$	$T^l_{c,t}$	$T^k_{c,t}$	$T^y_{c,t}$	$T^l_{c,t}$	$T^k_{c,t}$	$T^y_{c,t}$
Panel A: full period 1995-2016											
$R_{c,t}$	-0.025	0.023	-0.010	-0.020	0.684	-0.368**	0.875*	0.177	-1.376***	1.165	0.098
	(0.021)	(0.043)	(0.032)	(0.029)	(0.437)	(0.137)	(0.451)	(0.264)	(0.402)	(0.711)	(0.622)
$ICT_{c,t}$	-0.007	-0.255	-0.159**	0.084	-0.254	1.247***	-2.716***	1.215*	3.084**	-5.947***	2.706*
	(0.028)	(0.220)	(0.052)	(0.049)	(1.217)	(0.337)	(0.637)	(0.658)	(0.959)	(1.052)	(1.346)
$R * ICT_{c,t}$	-0.012	0.140	0.062	-0.050	-0.603	-0.974***	1.139*	-0.768	-1.696***	2.971***	-1.140
	(0.017)	(0.128)	(0.037)	(0.035)	(0.773)	(0.131)	(0.511)	(0.434)	(0.509)	(0.897)	(0.923)
R^2	0.999	.997	.998	.999	.974	.995	.974	.956	.994	.984	.942
N	214	214	214	214	214	214	214	214	214	214	214
Panel B: sub-period 1995-2007											
$R_{c,t}$	-0.046**	0.103	-0.128***	-0.001	-1.067*	0.250	-1.635***	0.318	1.408	-3.054**	1.448
	(0.016)	(0.076)	(0.032)	(0.031)	(0.488)	(0.451)	(0.472)	(0.361)	(0.945)	(0.963)	(1.203)
$ICT_{c,t}$	-0.012	-0.962*	-0.078	0.027	-0.049	0.428	-1.121	0.644	1.328	-2.963	1.794
	(0.035)	(0.452)	(0.076)	(0.074)	(1.200)	(0.927)	(1.203)	(0.711)	(2.125)	(1.933)	(2.591)
$R * ICT_{c,t}$	0.018	0.557**	0.026	-0.015	0.278	0.384	0.200	-0.306	0.707	0.512	-1.251
	(0.023)	(0.238)	(0.046)	(0.046)	(0.790)	(0.585)	(0.739)	(0.485)	(1.334)	(1.190)	(1.659)
R^2	0.999	.997	.999	0.999	.988	.995	.986	.972	.995	.989	.965
N	124	124	124	124	124	124	124	124	124	124	124
Panel C: sub-period 2008-2016											
$R_{c,t}$	-0.007	-0.043	0.018	-0.068***	0.100	0.186	0.904	-0.989***	1.499	0.953	-2.605***
	(0.029)	(0.071)	(0.083)	(0.020)	(1.358)	(0.462)	(0.926)	(0.221)	(1.020)	(1.508)	(0.719)
$ICT_{c,t}$	0.073	0.381	0.075	0.043	-1.555	-0.462	-0.876	-0.217	-0.792	-0.192	0.506
	(0.063)	(0.250)	(0.157)	(0.033)	(1.830)	(0.545)	(1.597)	(0.275)	(1.947)	(2.511)	(1.597)
$R * ICT_{c,t}$	-0.051*	-0.153	-0.082	-0.057***	-1.586**	-0.222	-0.434	-0.930***	1.782	-0.727	-0.890
	(0.027)	(0.143)	(0.084)	(0.011)	(0.672)	(0.442)	(0.433)	(0.211)	(1.419)	(1.385)	(0.528)
R^2	0.999	0.999	.999	0.999	.989	.998	.992	.985	.997	.995	.977
N	90	90	90	90	90	90	90	90	90	90	90

Findings:
Negative impact of AT on total tax revenues, ICT (robots) at cost of capital (labor) taxes.
Relative shares of other tax sources weakly increased.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement no. 822390

Prerequisites 1: Taxation and AT diffusion East (1995-2016)

	Taxes in ln of nat. currency				Taxes as % of GDP				Taxes as % of total tax		
	$lnT_{c,t}$	$lnT^{l}_{c,t}$	$lnT^{k}_{c,t}$	$lnT^{y}_{c,t}$	$T_{c,t}$	$T^{l}_{c,t}$	$T^{k}_{c,t}$	$T^{y}_{c,t}$	$T^{l}_{c,t}$	$T^{k}_{c,t}$	$T^{y}_{c,t}$
Panel A: full period 1995-2016											
$R_{c,t}$	-0.030	-0.042**	0.037	-0.062*	-0.294	-0.220	0.468	-0.542**	-0.568	2.044*	-1.416**
	(0.029)	(0.012)	(0.056)	(0.029)	(0.553)	(0.218)	(0.404)	(0.181)	(0.807)	(0.924)	(0.457)
$ICT_{c,t}$	0.024	0.096*	-0.063	-0.001	2.337	1.701*	0.154	0.482	2.672	-1.343	-1.310
	(0.048)	(0.040)	(0.083)	(0.075)	(1.205)	(0.793)	(0.479)	(0.442)	(1.634)	(0.913)	(1.443)
$R * ICT_{c,t}$	0.009	-0.019	0.024	0.033	-0.100	-0.405*	0.081	0.224	-1.171**	0.368	0.807
	(0.009)	(0.010)	(0.014)	(0.018)	(0.278)	(0.178)	(0.106)	(0.114)	(0.380)	(0.179)	(0.395)
R^2	0.999	0.999	.999	0.999	.948	.977	.845	.901	.962	.917	.909
N	97	97	97	97	97	97	97	97	97	97	97
Panel B: sub-period 1995-2007											
$R_{c,t}$	-0.022	-0.037	-0.014	0.000	-0.524	-0.123	0.115	-0.516	0.291	0.541	-0.861**
	(0.022)	(0.032)	(0.030)	(0.021)	(0.504)	(0.153)	(0.102)	(0.270)	(0.245)	(0.278)	(0.198)
$ICT_{c,t}$	0.031	0.030	-0.044	0.060	3.108	1.105	0.295	1.709	0.068	-1.872	1.833
	(0.115)	(0.139)	(0.085)	(0.152)	(1.653)	(1.233)	(0.779)	(1.208)	(2.888)	(2.125)	(3.833)
$R * ICT_{c,t}$	-0.002	0.013	-0.029	-0.002	-0.432	0.073	-0.346*	-0.159	0.679	-0.599	-0.031
	(0.018)	(0.022)	(0.020)	(0.024)	(0.232)	(0.172)	(0.132)	(0.204)	(0.508)	(0.363)	(0.725)
R^2	0.999	0.999	0.999	0.999	.973	.991	.9	.913	.99	.962	.932
N	52	52	52	52	52	52	52	52	52	52	52
Panel C: sub-period 2008-2016											
$R_{c,t}$	0.008	0.018	0.076	-0.047	1.161	0.526	0.733	-0.099	0.048	1.712	-1.633
	(0.013)	(0.039)	(0.056)	(0.023)	(0.969)	(0.408)	(0.528)	(1.063)	(1.804)	(1.217)	(1.768)
$ICT_{c,t}$	0.143	0.036	0.285*	0.184*	1.163	-0.387	1.146***	0.404	-3.195	3.875*	-0.952
	(0.078)	(0.122)	(0.105)	(0.077)	(3.117)	(1.413)	(0.150)	(1.616)	(5.180)	(1.700)	(2.422)
$R * ICT_{c,t}$	-0.011	0.028	-0.018	-0.036	0.960	0.316	0.152	0.492	-0.167	-0.307	0.526
	(0.018)	(0.030)	(0.052)	(0.033)	(0.565)	(0.200)	(0.190)	(0.434)	(0.349)	(0.672)	(0.507)
R^2	0.999	0.999	.999	0.999	.977	.982	.932	.936	.959	.949	.944
N	45	45	45	45	45	45	45	45	45	45	45

Findings:
Negative impact of AT on total tax revenues, ICT (robots) at cost of capital (labor) taxes.
Relative shares of other tax sources weakly increased.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement no. 82

Prerequisites 1: Taxation and AT diffusion South (1995-2016)

	Taxes in ln of nat. currency				Taxes as % of GDP				Taxes as % of total tax		
	$lnT_{c,t}$	$lnT^l_{c,t}$	$lnT^k_{c,t}$	$lnT^y_{c,t}$	$T_{c,t}$	$T^l_{c,t}$	$T^k_{c,t}$	$T^y_{c,t}$	$T^l_{c,t}$	$T^k_{c,t}$	$T^y_{c,t}$
Panel A: full period 1995-2016											
$R_{c,t}$	-0.158	-0.173	0.020	-0.272	-5.660**	-2.091	-0.575	-2.994	-2.005	3.854	-5.622
	(0.068)	(0.126)	(0.105)	(0.132)	(1.758)	(1.250)	(0.990)	(1.281)	(3.209)	(2.798)	(3.480)
$ICT_{c,t}$	-0.032	-0.084*	-0.006	-0.022	-0.708	-0.719**	0.120	-0.109	-1.770**	1.216	0.158
	(0.018)	(0.028)	(0.045)	(0.032)	(0.302)	(0.148)	(0.290)	(0.239)	(0.454)	(0.703)	(0.946)
$R * ICT_{c,t}$	0.011	0.020	-0.054	0.076	0.773	0.376	-0.420	0.817*	0.270	-2.347**	2.533*
	(0.032)	(0.037)	(0.055)	(0.040)	(0.426)	(0.353)	(0.182)	(0.291)	(0.762)	(0.677)	(0.877)
R^2	0.999	.999	.999	.999	.971	.967	.972	.959	.955	.935	.971
N	83	83	83	83	83	83	83	83	83	83	83
Panel B: sub-period 1995-2007											
$R_{c,t}$	-0.428**	-0.388	-0.784	-0.182	-12.186**	-2.540	-8.536*	-1.111	3.842	-11.378	8.483
	(0.125)	(0.245)	(0.380)	(0.242)	(3.262)	(2.450)	(2.830)	(2.351)	(3.875)	(7.832)	(8.293)
$ICT_{c,t}$	-0.140	-0.236**	-0.280	0.098	-5.795*	-3.293**	-3.255	0.753	-4.770**	-5.327	7.326
	(0.077)	(0.066)	(0.155)	(0.091)	(2.388)	(1.021)	(1.796)	(1.118)	(1.385)	(4.020)	(3.980)
$R * ICT_{c,t}$	-0.013	-0.071	0.023	-0.034	1.345*	-0.057	1.199*	0.203	-1.695	1.470	-0.860
	(0.030)	(0.045)	(0.060)	(0.038)	(0.423)	(0.436)	(0.493)	(0.444)	(0.789)	(1.588)	(1.445)
R^2	0.999	0.999	0.999	0.999	.981	.976	.99	.975	.981	.981	.992
N	47	47	47	47	47	47	47	47	47	47	47
Panel C: sub-period 2008-2016											
$R_{c,t}$	-0.329*	-0.152	-0.546	-0.194	-11.876**	-1.525	-7.294*	-3.057	6.052	-9.334	4.973
	(0.139)	(0.117)	(0.384)	(0.267)	(3.600)	(1.220)	(2.476)	(1.657)	(3.201)	(4.689)	(6.883)
$ICT_{c,t}$	0.039	-0.006	0.046	0.091**	1.605	0.025	0.735	0.845**	-2.092*	-0.063	1.298
	(0.031)	(0.024)	(0.076)	(0.028)	(0.893)	(0.198)	(0.796)	(0.228)	(0.881)	(1.872)	(1.178)
$R * ICT_{c,t}$	-0.066*	-0.094*	-0.084	-0.004	-1.393	-0.727	-0.705	0.039	-0.550	-0.199	1.862
	(0.021)	(0.039)	(0.047)	(0.058)	(0.703)	(0.346)	(0.465)	(0.494)	(1.159)	(1.370)	(2.353)
R^2	0.999	0.999	0.999	0.999	.992	.994	.99	.993	.986	.974	.993
N	36	36	36	36	36	36	36	36	36	36	36

Findings:

Negative impact of AT on total tax revenues, ICT (robots) at cost of capital (labor) taxes.

Relative shares of other tax sources weakly increased.

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Replacement effect - North

	ln $wL_{i,c,t}$	ln $w_{i,c,t}$	ln $L_{i,c,t}$	ln $rK_{i,c,t}$	ln $r_{i,c,t}$	ln $K_{i,c,t}$
Panel A: full period 1995-2016						
$R_{i,c,t}$	-0.006	0.007	-0.013	-0.012	-0.010	0.057
	(0.036)	(0.009)	(0.033)	(0.047)	(0.010)	(0.037)
$ICT_{i,c,t}$	0.006	0.004	0.002	0.029	0.001	0.007
	(0.013)	(0.004)	(0.013)	(0.020)	(0.013)	(0.015)
$R * ICT_{i,c,t}$	-0.002	0.005*	-0.007	0.009	-0.004	0.014*
	(0.008)	(0.002)	(0.008)	(0.012)	(0.003)	(0.008)
R^2	.997	.998	.997	.947	.901	.994
N	2958	2958	2958	2925	2958	2958
Panel B: sub-period 1995-2007						
$R_{i,c,t}$	0.041	0.010	0.031	0.096	0.002	0.071***
	(0.031)	(0.007)	(0.027)	(0.076)	(0.007)	(0.023)
$ICT_{i,c,t}$	0.008	0.001	0.007	0.004	0.002	0.019
	(0.009)	(0.005)	(0.011)	(0.034)	(0.015)	(0.017)
$R * ICT_{i,c,t}$	0.003	-0.001	0.004	-0.001	-0.001	0.010
	(0.009)	(0.003)	(0.008)	(0.024)	(0.004)	(0.007)
R^2	.998	.999	.998	.953	.92	.998
N	1742	1742	1742	1718	1742	1742
Panel C: sub-period 2008-2016						
$R_{i,c,t}$	-0.053**	-0.005	-0.048**	0.003	0.000	-0.023
	(0.022)	(0.012)	(0.020)	(0.074)	(0.004)	(0.023)
$ICT_{i,c,t}$	-0.060	0.024	-0.085*	-0.165	-0.011	-0.086
	(0.041)	(0.015)	(0.038)	(0.128)	(0.006)	(0.080)
$R * ICT_{i,c,t}$	-0.011	-0.001	-0.010	0.052	-0.002	0.022
	(0.014)	(0.006)	(0.012)	(0.036)	(0.002)	(0.013)
R^2	.999	.999	.999	.971	.918	.998
N	1215	1215	1215	1206	1215	1215

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Replacement effect - East

	ln $wL_{i,c,t}$	ln $w_{i,c,t}$	ln $L_{i,c,t}$	ln $rK_{i,c,t}$	ln $r_{i,c,t}$	ln $K_{i,c,t}$
Panel A: full period 1995-2016						
$R_{i,c,t}$	-0.012	0.031	-0.043***	0.036	0.002	-0.029
	(0.022)	(0.019)	(0.014)	(0.023)	(0.003)	(0.031)
$ICT_{i,c,t}$	0.014	-0.006	0.021	0.021	-0.012***	0.043*
	(0.020)	(0.021)	(0.013)	(0.023)	(0.002)	(0.022)
$R * ICT_{i,c,t}$	-0.009	0.010	-0.019***	0.004	0.002**	-0.016
	(0.007)	(0.007)	(0.004)	(0.007)	(0.001)	(0.009)
R^2	.998	.997	.992	.985	.99	.998
N	909	909	909	909	814	814
Panel B: sub-period 1995-2007						
$R_{i,c,t}$	-0.038	-0.029	-0.009	-0.017	-0.004	-0.009
	(0.043)	(0.037)	(0.029)	(0.053)	(0.002)	(0.022)
$ICT_{i,c,t}$	0.008	-0.011	0.019	-0.000	-0.007***	0.043***
	(0.043)	(0.034)	(0.030)	(0.042)	(0.002)	(0.013)
$R * ICT_{i,c,t}$	0.030	0.057	-0.027	0.055	0.009*	-0.004
	(0.056)	(0.045)	(0.035)	(0.069)	(0.004)	(0.043)
R^2	.998	.997	.992	.984	.993	.998
N	459	459	459	459	409	409
Panel C: sub-period 2008-2016						
$R_{i,c,t}$	0.010	0.017	-0.007	-0.038	0.005	-0.002
	(0.016)	(0.016)	(0.010)	(0.041)	(0.004)	(0.015)
$ICT_{i,c,t}$	-0.013	-0.003	-0.010	0.072	0.001	0.011
	(0.017)	(0.019)	(0.018)	(0.058)	(0.009)	(0.043)
$R * ICT_{i,c,t}$	0.001	0.006	-0.005	-0.018	0.004**	-0.007
	(0.007)	(0.007)	(0.003)	(0.016)	(0.002)	(0.009)
R^2	.999	.999	.997	.992	.976	0.999
N	450	450	450	450	405	405

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Replacement effect - South

	ln $wL_{i,c,t}$	ln $w_{i,c,t}$	ln $L_{i,c,t}$	ln $rK_{i,c,t}$	ln $r_{i,c,t}$	ln $K_{i,c,t}$
Panel A: full period 1995-2016						
$R_{i,c,t}$	-0.017	0.079*	-0.096	-0.239	-0.033***	-0.036
	(0.072)	(0.041)	(0.073)	(0.186)	(0.010)	(0.052)
$ICT_{i,c,t}$	0.068***	0.035	0.033	-0.065	0.011**	0.020
	(0.016)	(0.024)	(0.022)	(0.064)	(0.005)	(0.012)
$R * ICT_{i,c,t}$	0.023	0.014	0.010	0.067	0.015***	-0.050**
	(0.024)	(0.012)	(0.024)	(0.062)	(0.005)	(0.020)
R^2	.996	.967	.995	.952	.987	.997
N	981	981	981	959	981	981
Panel B: sub-period 1995-2007						
$R_{i,c,t}$	0.026	0.052**	-0.026	-0.085*	-0.007	-0.003
	(0.020)	(0.022)	(0.023)	(0.046)	(0.006)	(0.029)
$ICT_{i,c,t}$	0.090*	0.097	-0.007	-0.378	-0.009	0.054
	(0.042)	(0.062)	(0.045)	(0.232)	(0.008)	(0.036)
$R * ICT_{i,c,t}$	-0.013	-0.017**	0.005	-0.048*	0.004*	-0.017*
	(0.009)	(0.007)	(0.007)	(0.025)	(0.002)	(0.009)
R^2	.998	.97	.998	.959	.992	.999
N	576	576	576	563	576	576
Panel C: sub-period 2008-2016						
$R_{i,c,t}$	-0.068	0.184	-0.252	-0.710	-0.055	-0.052
	(0.159)	(0.131)	(0.151)	(0.547)	(0.035)	(0.084)
$ICT_{i,c,t}$	0.084**	0.048	0.036	0.114	0.029**	0.036
	(0.029)	(0.029)	(0.033)	(0.097)	(0.013)	(0.023)
$R * ICT_{i,c,t}$	0.099*	0.007	0.092	0.202	0.025*	-0.103**
	(0.053)	(0.031)	(0.052)	(0.140)	(0.011)	(0.041)
R^2	.998	.972	.998	.978	.874	.999
N	405	405	405	396	405	405

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Reinstatement effect North

	ln $w_{c,t}$	ln $L_{c,t}$	ln $r_{c,t}$	ln $K_{c,t}$	$Services_{c,t}$	$Gini^{w}_{c,t}$
Panel A: full period 1995-2016						
$R_{c,t}$	-0.078***	-0.036**	-0.134***	-0.034*	-0.883***	-0.003
	(0.012)	(0.011)	(0.028)	(0.018)	(0.229)	(0.008)
$ICT_{c,t}$	0.170**	-0.070	0.034	0.046	1.564	0.103**
	(0.061)	(0.040)	(0.116)	(0.073)	(1.811)	(0.034)
$R * ICT_{c,t}$	-0.070*	0.036	-0.013	0.004	0.289	-0.050**
	(0.035)	(0.029)	(0.068)	(0.050)	(0.979)	(0.021)
R^2	.999	0.999	.945	.999	.96	.92
N	214	214	214	214	214	214
Panel B: sub-period 1995-2007						
$R_{c,t}$	-0.037	-0.026	-0.083**	0.023	-1.947**	-0.012
	(0.023)	(0.020)	(0.033)	(0.019)	(0.746)	(0.008)
$ICT_{c,t}$	0.055	-0.053	0.082	-0.102	1.579	0.099***
	(0.053)	(0.037)	(0.097)	(0.072)	(1.827)	(0.023)
$R * ICT_{c,t}$	0.022	0.007	-0.006	0.077*	-1.217	-0.034**
	(0.027)	(0.024)	(0.051)	(0.036)	(0.804)	(0.013)
R^2	.999	0.999	.955	0.999	.971	.966
N	124	124	124	124	124	124
Panel C: sub-period 2008-2016						
$R_{c,t}$	0.032*	-0.041	-0.017	-0.031	-0.329	0.012**
	(0.017)	(0.041)	(0.041)	(0.021)	(0.721)	(0.005)
$ICT_{c,t}$	-0.001	0.038	-0.048	0.068	7.653**	-0.013
	(0.010)	(0.052)	(0.074)	(0.052)	(2.442)	(0.010)
$R * ICT_{c,t}$	0.015**	0.000	0.033	0.050	-2.464*	0.020*
	(0.006)	(0.035)	(0.058)	(0.030)	(1.164)	(0.009)
R^2	0.999	0.999	.877	0.999	.983	.974
N	90	90	90	90	90	90

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Reinstatement effect East

	$\ln w_{c,t}$	$\ln L_{c,t}$	$\ln r_{c,t}$	$\ln K_{c,t}$	$Services_{c,t}$	$Gini^{w}_{c,t}$
Panel A: full period 1995-2016						
$R_{c,t}$	-0.145***	0.053**	-0.113***	0.023	0.216	0.057*
	(0.018)	(0.015)	(0.022)	(0.017)	(0.394)	(0.026)
$ICT_{c,t}$	0.274**	-0.064	0.232**	-0.023	-5.645**	0.008
	(0.090)	(0.040)	(0.068)	(0.034)	(1.662)	(0.058)
$R * ICT_{c,t}$	-0.030*	0.005	-0.013	-0.012*	0.522	-0.011
	(0.013)	(0.008)	(0.009)	(0.005)	(0.317)	(0.011)
R^2	.999	.998	.948	0.999	.978	.825
N	97	97	97	97	97	97
Panel B: sub-period 1995-2007						
$R_{c,t}$	-0.118*	-0.021	-0.039	-0.048**	0.102	0.055**
	(0.045)	(0.014)	(0.054)	(0.016)	(0.405)	(0.019)
$ICT_{c,t}$	0.596***	-0.165***	0.279	-0.043	-10.135***	0.128
	(0.107)	(0.027)	(0.135)	(0.060)	(1.581)	(0.066)
$R * ICT_{c,t}$	-0.094**	0.028***	-0.035	0.012	1.121**	-0.024*
	(0.022)	(0.002)	(0.034)	(0.011)	(0.377)	(0.010)
R^2	.999	.999	.947	0.999	.991	.933
N	52	52	52	52	52	52
Panel C: sub-period 2008-2016						
$R_{c,t}$	-0.057*	0.025	-0.031	0.007	-1.018	0.006
	(0.025)	(0.026)	(0.023)	(0.026)	(0.502)	(0.008)
$ICT_{c,t}$	0.158	0.182**	0.000	0.112	-1.852	-0.033*
	(0.114)	(0.057)	(0.080)	(0.100)	(1.968)	(0.015)
$R * ICT_{c,t}$	-0.031***	-0.020	-0.038	-0.022	-0.810**	0.007*
	(0.006)	(0.030)	(0.018)	(0.021)	(0.212)	(0.003)
R^2	0.999	.999	.883	0.999	.995	.909
N	45	45	45	45	45	45

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Reinstatement effect South

	$\ln w_{c,t}$	$\ln L_{c,t}$	$\ln r_{c,t}$	$\ln K_{c,t}$	$Services_{c,t}$	$Gini^{w}_{c,t}$
Panel A: full period 1995-2016						
$R_{c,t}$	-0.163	-0.034	0.018	-0.084**	-3.596*	-0.021
	(0.083)	(0.040)	(0.061)	(0.019)	(1.304)	(0.030)
$ICT_{c,t}$	0.030	0.043**	-0.044*	0.099***	0.712	0.002
	(0.015)	(0.013)	(0.017)	(0.006)	(0.355)	(0.005)
$R * ICT_{c,t}$	0.034	-0.064**	-0.031*	-0.031***	0.944*	0.010
	(0.017)	(0.014)	(0.010)	(0.005)	(0.401)	(0.007)
R^2	.997	0.999	.982	0.999	.995	.926
N	83	83	83	83	83	83
Panel B: sub-period 1995-2007						
$R_{c,t}$	-0.181*	-0.053	-0.054	-0.111**	-0.455	-0.118
	(0.058)	(0.057)	(0.090)	(0.031)	(2.112)	(0.080)
$ICT_{c,t}$	-0.018	-0.015	-0.000	0.045***	2.840	-0.082
	(0.046)	(0.030)	(0.061)	(0.007)	(1.340)	(0.037)
$R * ICT_{c,t}$	0.014	-0.048*	-0.012	-0.019*	0.353	0.018
	(0.016)	(0.018)	(0.030)	(0.007)	(0.359)	(0.017)
R^2	.998	0.999	.989	0.999	.997	.945
N	47	47	47	47	47	47
Panel C: sub-period 2008-2016						
$R_{c,t}$	0.262***	0.112	0.309*	0.101*	0.011	0.017
	(0.041)	(0.050)	(0.105)	(0.042)	(2.620)	(0.033)
$ICT_{c,t}$	0.006	-0.050	-0.110**	0.031*	1.791*	0.005
	(0.011)	(0.032)	(0.033)	(0.012)	(0.643)	(0.008)
$R * ICT_{c,t}$	0.022	0.015	-0.004	0.019	0.394	0.010
	(0.012)	(0.027)	(0.034)	(0.009)	(0.684)	(0.008)
R^2	0.999	0.999	.946	0.999	.996	.976
N	36	36	36	36	36	36

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Real-income effect North

	ln $wL_{c,t}$	ln $rK_{c,t}$	ln $(wL+rK)_{c,t}$	ln $pQ_{c,t}$	ln $Q_{c,t}$	ln $p_{c,t}$	ln $LProd_{c,t}$	ln $TFP_{c,t}$
Panel A: full period 1995-2016								
$R_{c,t}$	-0.158***	-0.140	-0.166**	-0.141**	-0.029	-0.051***	-0.000	0.029**
	(0.038)	(0.078)	(0.058)	(0.052)	(0.019)	(0.006)	(0.015)	(0.011)
$ICT_{c,t}$	0.117	-0.038	0.068	0.064	-0.002	0.025**	0.068*	-0.005
	(0.077)	(0.077)	(0.083)	(0.071)	(0.037)	(0.010)	(0.034)	(0.030)
$R * ICT_{c,t}$	-0.071	-0.029	-0.066	-0.076	-0.001	-0.022**	-0.043*	0.030
	(0.055)	(0.069)	(0.065)	(0.058)	(0.021)	(0.008)	(0.020)	(0.018)
R^2	.998	.993	.997	.997	0.999	.992	0.999	.885
N	214	214	214	214	171	171	171	171
Panel B: sub-period 1995-2007								
$R_{c,t}$	-0.059*	0.021	-0.025	-0.003	-0.034	-0.045***	0.015	0.018
	(0.029)	(0.062)	(0.036)	(0.039)	(0.022)	(0.008)	(0.015)	(0.010)
$ICT_{c,t}$	-0.019	-0.189	-0.093	-0.084	0.029	0.019	0.061	-0.025
	(0.094)	(0.168)	(0.116)	(0.114)	(0.056)	(0.013)	(0.045)	(0.016)
$R * ICT_{c,t}$	0.038	0.055	0.053	0.045	-0.011	-0.012	-0.007	0.028**
	(0.051)	(0.077)	(0.057)	(0.057)	(0.034)	(0.009)	(0.025)	(0.009)
R^2	.999	.997	.999	.999	0.999	.992	0.999	.92
N	124	124	124	124	99	99	99	99
Panel C: sub-period 2008-2016								
$R_{c,t}$	0.001	-0.082	-0.061	-0.093	0.025	-0.005	-0.003	0.017
	(0.030)	(0.115)	(0.062)	(0.055)	(0.027)	(0.019)	(0.020)	(0.012)
$ICT_{c,t}$	0.041	-0.008	0.019	0.018	0.028	0.023	-0.041*	0.038**
	(0.051)	(0.171)	(0.094)	(0.070)	(0.018)	(0.018)	(0.021)	(0.016)
$R * ICT_{c,t}$	0.020	0.020	0.014	-0.025	0.030	-0.035**	0.015	0.015
	(0.034)	(0.105)	(0.067)	(0.046)	(0.021)	(0.012)	(0.019)	(0.014)
R^2	0.999	.998	.999	0.999	0.999	.962	0.999	.989
N	90	90	90	90	72	72	72	72

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Real-income effect East

	ln $wL_{c,t}$	ln $rK_{c,t}$	ln $(wL+rK)_{c,t}$	ln $pQ_{c,t}$	ln $Q_{c,t}$	ln $p_{c,t}$	ln $LProd_{c,t}$	ln $TFP_{c,t}$
Panel A: full period 1995-2016								
$R_{c,t}$	-0.106***	-0.059	-0.086**	-0.084	0.059**	-0.090***	-0.009	-0.002
	(0.021)	(0.044)	(0.029)	(0.041)	(0.018)	(0.013)	(0.019)	(0.011)
$ICT_{c,t}$	-0.016	-0.186	-0.098	-0.026	-0.007	-0.198**	0.049	-0.185**
	(0.061)	(0.113)	(0.067)	(0.102)	(0.038)	(0.050)	(0.035)	(0.048)
$R * ICT_{c,t}$	0.010	0.022	0.016	0.008	-0.016	0.036*	-0.024	0.026*
	(0.014)	(0.028)	(0.018)	(0.025)	(0.009)	(0.014)	(0.011)	(0.011)
R^2	.999	.999	.999	.999	0.999	.983	0.999	.933
N	97	97	97	97	76	76	76	76
Panel B: sub-period 1995-2007								
$R_{c,t}$	-0.181*	-0.040	-0.130*	-0.106	-0.063*	-0.089	-0.055	-0.032*
	(0.066)	(0.038)	(0.052)	(0.063)	(0.023)	(0.046)	(0.028)	(0.013)
$ICT_{c,t}$	0.138	-0.542***	-0.126	-0.106	-0.031	-0.151	0.144	-0.241**
	(0.134)	(0.117)	(0.117)	(0.160)	(0.064)	(0.093)	(0.080)	(0.043)
$R * ICT_{c,t}$	0.000	0.102**	0.045	0.052	0.013	0.021	-0.020	0.043**
	(0.034)	(0.034)	(0.033)	(0.045)	(0.013)	(0.018)	(0.016)	(0.010)
R^2	.999	.999	.999	.999	0.999	.99	0.999	.988
N	52	52	52	52	40	40	40	40
Panel C: sub-period 2008-2016								
$R_{c,t}$	-0.032	0.006	-0.016	0.012	0.072**	-0.022	0.019	-0.018*
	(0.036)	(0.040)	(0.031)	(0.036)	(0.022)	(0.010)	(0.016)	(0.006)
$ICT_{c,t}$	0.292	0.093	0.164	0.157	0.089	-0.019	-0.065	0.017
	(0.161)	(0.124)	(0.109)	(0.098)	(0.112)	(0.033)	(0.116)	(0.019)
$R * ICT_{c,t}$	-0.080*	-0.062**	-0.069*	-0.057*	-0.021	-0.016	-0.006	-0.013*
	(0.032)	(0.019)	(0.026)	(0.022)	(0.009)	(0.008)	(0.017)	(0.005)
R^2	0.999	0.999	0.999	0.999	0.999	.917	0.999	.985
N	45	45	45	45	36	36	36	36

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Real-income effect South

	ln $wL_{c,t}$	ln $rK_{c,t}$	ln $(wL+rK)_{c,t}$	ln $pQ_{c,t}$	ln $Q_{c,t}$	ln $p_{c,t}$	ln $LProd_{c,t}$	ln $TFP_{c,t}$
Panel A: full period 1995-2016								
$R_{c,t}$	-0.193	0.176**	-0.055	0.010	-0.008	-0.036	0.039	0.056
	(0.140)	(0.040)	(0.082)	(0.045)	(0.041)	(0.041)	(0.022)	(0.021)
$ICT_{c,t}$	0.055	0.092**	0.070**	0.097***	0.092	0.084**	0.027	-0.006
	(0.023)	(0.021)	(0.013)	(0.015)	(0.053)	(0.019)	(0.033)	(0.016)
$R * ICT_{c,t}$	-0.017	-0.162**	-0.071*	-0.103***	-0.078*	0.009	-0.021	-0.016
	(0.038)	(0.030)	(0.023)	(0.014)	(0.018)	(0.014)	(0.016)	(0.009)
R^2	.999	.999	.999	0.999	0.999	.998	.999	.994
N	83	83	83	83	61	61	61	61
Panel B: sub-period 1995-2007								
$R_{c,t}$	-0.275***	0.129	-0.122*	-0.130*	-0.242	0.045	-0.122	-0.013
	(0.038)	(0.141)	(0.039)	(0.051)	(0.170)	(0.087)	(0.208)	(0.079)
$ICT_{c,t}$	-0.073	0.297**	0.064	0.078**	0.060*	0.022	0.033	-0.048*
	(0.050)	(0.063)	(0.043)	(0.024)	(0.017)	(0.013)	(0.029)	(0.014)
$R * ICT_{c,t}$	-0.035*	-0.075	-0.050**	-0.047**	0.002	-0.040	0.042	-0.009
	(0.013)	(0.036)	(0.014)	(0.012)	(0.064)	(0.034)	(0.081)	(0.029)
R^2	0.999	0.999	0.999	0.999	0.999	0.999	0.999	.999
N	47	47	47	47	34	34	34	34
Panel C: sub-period 2008-2016								
$R_{c,t}$	0.292*	0.366*	0.315**	0.303*	0.340**	0.123	0.121	0.066*
	(0.110)	(0.122)	(0.084)	(0.098)	(0.059)	(0.070)	(0.063)	(0.018)
$ICT_{c,t}$	-0.029	-0.058	-0.040	-0.051	-0.113*	0.076	-0.028	-0.017
	(0.035)	(0.033)	(0.020)	(0.026)	(0.029)	(0.032)	(0.024)	(0.017)
$R * ICT_{c,t}$	0.036	-0.071	-0.005	0.012	-0.022	0.003	-0.006	0.002
	(0.037)	(0.035)	(0.023)	(0.028)	(0.016)	(0.013)	(0.017)	(0.009)
R^2	0.999	0.999	0.999	0.999	0.999	.97	0.999	.997
N	36	36	36	36	27	27	27	27

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