GAIDAR INSTITUTE FOR ECONOMIC POLICY

# ANALYSIS OF THE FACTORS OF ECONOMIC GROWTH IN RUSSIA'S REGIONS BASED ON THE LATENT CLASS MODEL (IN PROGRESS)

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# MOTIVATION

- In most studies on economic growth a set of classical factors is considered [Barro, 1989; Romer, 1990; Mankiw et al., 1992; Knight et al., 1993; ... ]:
  - *GDP at the beginning of the period* (conditional $\beta$-convergence)
  - *savings rate* (or the share of investments in fixed assets in GDP)
  - *stock or rate of human capital accumulation*
  - *innovation* — the process of creating innovations, including the creation, search and implementation of new ideas in business and the economy
  - ...
- There are global processes that should be taken into account when modeling economic growth:
  - *population ageing* — the process of increasing the share of 50-60+ people among the employed or the population
  - *digitalization* — the process of introducing new digital technologies into all areas of life, including manufacturing, trade, etc.

# CONTENT

- A brief review of the factors of economic growth
- Modeling of economic growth based on the Russia's regions data
- Base results for the full sample of regions
- Revealing of clusters by the sensitivity of economic growth to digitalization based on the Latent Class Model
- Estimates for the identified cluster of regions

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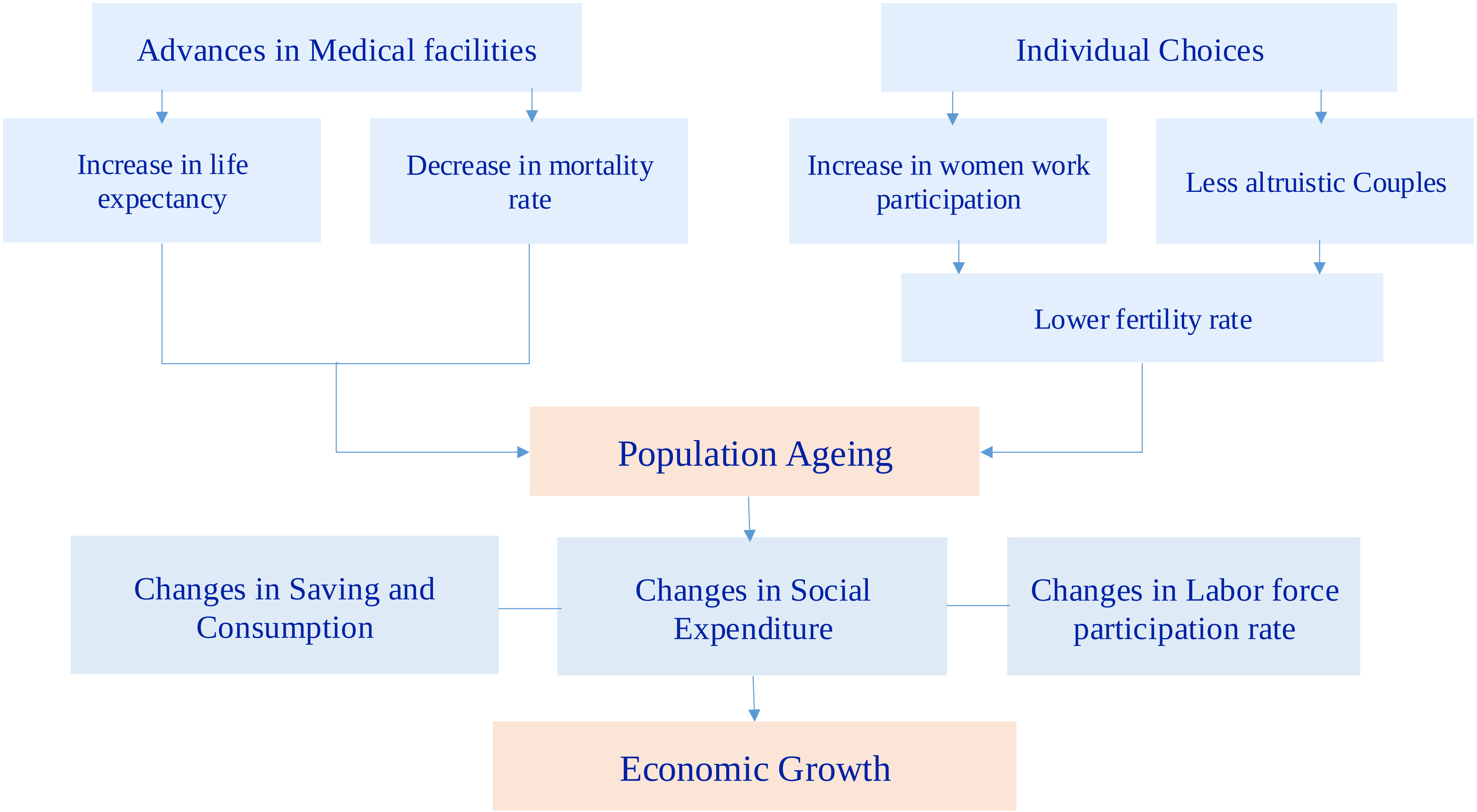
# A REVIEW OF THE FACTORS OF ECONOMIC GROWTH

- Population ageing
- Digitalization
- Other factors
  - Initial conditions (convergence)
  - Investments in fixed assets
  - Human capital (education)
  - R&D Expenditures
  - Import of equipment

# POPULATION AGEING: THE MECHANISMS




*Source*: Maity, S., & Sinha, A. (2021)

# POPULATION AGEING: (–) EFFECT ON ECONOMIC GROWTH

- LABOR PRODUCTIVITY: due to ageing ↓ physical and cognitive abilities => harder to learn new skills => with ↑ share of older workers => ↓ labor productivity growth => ↓ growth
  - The population ageing contributed to a slowdown in the growth of TFP in both AES (by an average of 0.2–0.5 p. p. per year) and EME (by 0.1 p. p. per year) in 2000-2014 [Poplawski–Ribeiro, 2020]
- LABOR SUPPLY: population ageing => ↓ labor supply => ↑ price of labor => ↑ costs of firms => ↓ output and growth
  - The forecast for OECD countries for 2020-50: due to population ageing, growth is ↓ by 0.8 p.p. if working age is estimated retrospectively, and by 0.4 p.p. if estimated prospectively, i.e. taking into account improvements in health and life expectancy [Kotschy, Bloom, 2023]
- GROWING BURDEN ON THE BUDGET SYSTEM: population ageing => ↑ the burden on the budget system => 1) ↑ in taxes on working individuals => ↓ hours worked, capital accumulation and private investment; => 2) ↓ in productive government spending
- PUBLIC DEMAND: with age ↑ the demand for goods from sectors with a lower contribution to economic growth

# POPULATION AGEING: (+) EFFECT ON ECONOMIC GROWTH

- AUTOMATIZATION: population ageing creates more incentives for labor-saving innovations => can contribute to ↑ investments in automatization and robotics by enterprises and the state
  - There is a positive association between ageing and the introduction of robotic technologies (endogenous technology response) [Acemoglu, Restrepo, 2017]
- INCREASE IN HEALTHY LIFE EXPECTANCY: a comparatively healthier and disability-free elderly population can continue to work productively (and generally not retire), contributing to the development of the economy
  - Improved health of the population aged 55-69 is associated with higher GDP growth rates [Cylus, Tayara, 2021]
- HUMAN CAPITAL: older workers with a high level of education learn new skills more easily => compensation for lower productivity and growth rates [Aksoy et al., 2019]
  - Higher levels of education among older people increase their participation in the workforce [Maestas et al., 2016]
- MENTORING: older workers learn young workers => complementarity of skills (imperfect interchangeability of human capital of young and older workers)
  - For most countries, the maximum per capita production growth is achieved when there are ~ 0.95 workers aged 35-54 per employee aged 15-34 (~ 1 mentor per 1 young employee) [Gomez, De Cos, 2008]

# DIGITALIZATION: (+) EFFECT ON ECONOMIC GROWTH

- ICT – the basis of digitalization, expands opportunities for business growth => ICT is a factor of economic growth [Habibi, Zabardast, 2020]
- Channels of ICT impact on economic growth [Vu et al., 2020]:
    - ICT capital growth => productivity and output growth in this sector => ↑ output
    - Automation => labor release => optimization of business processes
    - ↑ the speed of idea generation => introducing more innovations
    - ↑ the speed of the spread of innovations between firms => ↓ costs and ↑ opportunities
    - Forecasting demand using algorithms => ↓ costs
    - ...
- The estimated contribution of ICT capital to GDP growth may range from 0.1 to 1.0 p. p. [Vu et al., 2020]
- The additional investments are needed, especially in organizational transformation, so that investments in ICT can stimulate economic growth and productivity (including employee skills)
- Different return on investment over time: in the LR (from 3 to 7 years) Investments in ICT contribute more to productivity growth than in the SR [Brynjolfsson, Hitt, 2003]

# DIGITALIZATION: (–) EFFECT ON ECONOMIC GROWTH

- Monopolization of the market by firms with a high share of intangible assets (IA):
  - IA reduce marginal costs and increase fixed costs, which gives firms with a high proportion of IA a competitive advantage, preventing new firms from entering the market [De Ridder, 2024]
- Lack of incentives for small firms to invest in new technologies
  - Reducing the costs associated with the development of several markets allows firms with high margins to dominate and displace less efficient firms, which reduces competition and incentives for innovation, despite the overall increase in market concentration and rents [Aghion, et al., 2023]
- A decrease in the intensity of knowledge spillovers from advanced firms to laggards leads to a decrease in innovation activity and a slowdown in economic growth [Akcigit, Ates, 2023]

# OTHER FACTORS

- (–) Initial conditions (convergence)
  - distance from the technological frontier (TFP)
  - attracting FDI
  - structural and sectoral transformation
- (+) Investments in fixed assets
  - $\uparrow$ K => $\uparrow$ Y => $\uparrow$ y
- Human capital (education)
  - (+) another type of capital: $\uparrow$ H => $\uparrow$ Y => $\uparrow$ y
  - (–) distance from the leaders
- (+) R&D expenditures => innovations (technologies and/or products) =>
  - improvement of production technology (cost reduction, quality improvement)
  - $\uparrow$ diversity of products
- (+) Import of equipment
  - using new technologies without high R&D costs

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# ESTIMATES FOR THE RUSSIA'S REGIONS

- *The source*: the annual collections of Rosstat "Regions of Russia. Socio-economic indicators"
- T = 21 years, 2001–2021 (4 five-year periods => ↓ of cyclical fluctuations)

| 1 period | 2 period | 3 period | 4 period |
|---|---|---|---|
| 2002–2006 | 2007–2011 | 2012–2016 | 2017–2021 |
| GRP0 = 2001 | GRP0 = 2006 | GRP0 = 2011 | GRP0 = 2016 |

- N = 77 regions (due to data limitation):
  - excluded: Crimea and Sevastopol, Chechen Republic, Jewish Autonomous Region, Chukotka Autonomous Region
- All indicators (except GRP at the beginning of each period) are averaged within each 5–year period

# DESCRIPTION OF VARIABLES USED

| Variables | | Description |
|---|---|---|
| GROWTH | Economic growth | Indices of the physical volume of GRP per capita (in constant prices; in % of the previous year) |
| GRP_0 | Initial per capita income | Initial GRP per capita in constant prices, 10 thous. rub. |
| INV | Investments in fixed assets | Construction costs, reconstruction of facilities (lead to an increase in their initial cost), purchase of machinery, equipment, vehicles, etc., as % of GRP |
| WORK50_59 | Workforce ageing | The share of employed people aged 50-59 among all employed in the region, % |
| HIGH_ED | Human capital stock | The share of employed with higher education among all employed in the region, % |
| IMP | Import of equipment | The share of imports of machinery, equipment and vehicles, as % of GRP |
| RD_EXP | R&D Expenditures | Internal R&D expenses from all sources, as % of GRP |
| ICT | Digitalization | Total ICT expenses (including capital and current expenses for the development, acquisition, implementation and use of ICT), as % of GRP |

# ECONOMETRIC MODEL

- The considered model

$$GROWTH_{it} = \alpha + \beta_{grp0} \cdot GRP_{0_{it}} + \beta_{inv} \cdot INV_{it} + \boldsymbol{\beta_{work}} \cdot WORK50\_59_{it}$$

$$+\beta_{highed} \cdot highed_{it} + \beta_{imp} \cdot IMP_{it} + \beta_{rd} \cdot RD_{it} + \boldsymbol{\beta_{ict}} \cdot ICT_{it} + \varepsilon_{it}$$

- Between-region variation
- Relative (shares) rather than absolute (monetary) indicators are considered in order to take into account the heterogeneity of regions in size, prices and population
- Hypotheses:
  - *Do regions with with a higher share of ageing workers in the labor force show lower economic growth rates compared to other regions?*
  - *Do regions with higher ICT expenses in GRP show higher economic growth rates compared to other regions?*

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# BASE RESULTS FOR THE FULL SAMPLE, 2001-2021

| Panel Pool Model | (1) | (2) | (3) | (4) | (5) | (6) | |
|---|---|---|---|---|---|---|---|
| Initial GRP per capita, 10 thous. rub. | –0.096** | –0.095*** | –0.091** | –0.095** | –0.091*** | –0.089** | |
| | (0.038) | (0.035) | (0.036) | (0.039) | (0.034) | (0.035) | |
| Investments in fixed assets, as % of GRP | 0.047* | 0.041* | 0.056** | 0.046* | 0.050** | 0.050** | |
| | (0.027) | (0.025) | (0.026) | (0.027) | (0.024) | (0.024) | |
| **Employed people aged 50-59 among all employed, %** | –0.317*** | –0.337*** | –0.338*** | –0.318*** | –0.350*** | –0.354*** | $\beta_{work}$ |
| | (0.084) | (0.083) | (0.084) | (0.083) | (0.083) | (0.081) | |
| Employed with higher education among all employed, % | –0.125*** | –0.133*** | –0.139*** | –0.122*** | –0.143*** | –0.138*** | |
| | (0.042) | (0.038) | (0.036) | (0.041) | (0.035) | (0.035) | |
| Import of machinery, equipment and vehicles, as % of GRP | | 0.054*** | | | 0.042*** | 0.041*** | |
| | | (0.019) | | | (0.015) | (0.016) | |
| Internal R&D expenses from all sources, as % of GRP | | | 0.654*** | | 0.552*** | 0.633*** | |
| | | | (0.223) | | (0.205) | (0.212) | |
| **Total ICT expenses, as % of GRP** | | | | –0.141 | | –0.364* | $\beta_{ict}$ |
| | | | | (0.249) | | (0.209) | |
| Intercept | 12.735*** | 13.183*** | 12.761*** | 12.863*** | 13.103*** | 13.438*** | |
| | (1.416) | (1.399) | (1.391) | (1.459) | (1.391) | (1.399) | |
| Adjusted $R^2$ | 0.313 | 0.345 | 0.357 | 0.312 | 0.374 | 0.382 | |

*Notes: robust standard errors are in parentheses, *p < 0.1, **p < 0.05, ***p < 0.01*

# CONTENT

# LATENT CLASS MODEL (LCM)

- LCM – a mixture of standard linear regression models [Leisch, 2004]
- Hypothesis:
  - *Regions are heterogeneous in terms of the sensitivity of economic growth rates to the share of ICT expenses in GRP (digitalization)*
- Mechanisms:
  - *Different economic structure, different optimal skill levels in industries => in some regions, digitalization can help reach the technological frontier*
  - *Different skill levels (important for mastering digital skills) => in some regions there are not enough high-qualified workers => there is no effect from digitalization*
- Suppose there are 2 latent classes
- We use LCM to divide the regions into 2 clusters, and then estimate the base model on the obtained subsamples to determine whether the effect will be different if we do not pool all the regions

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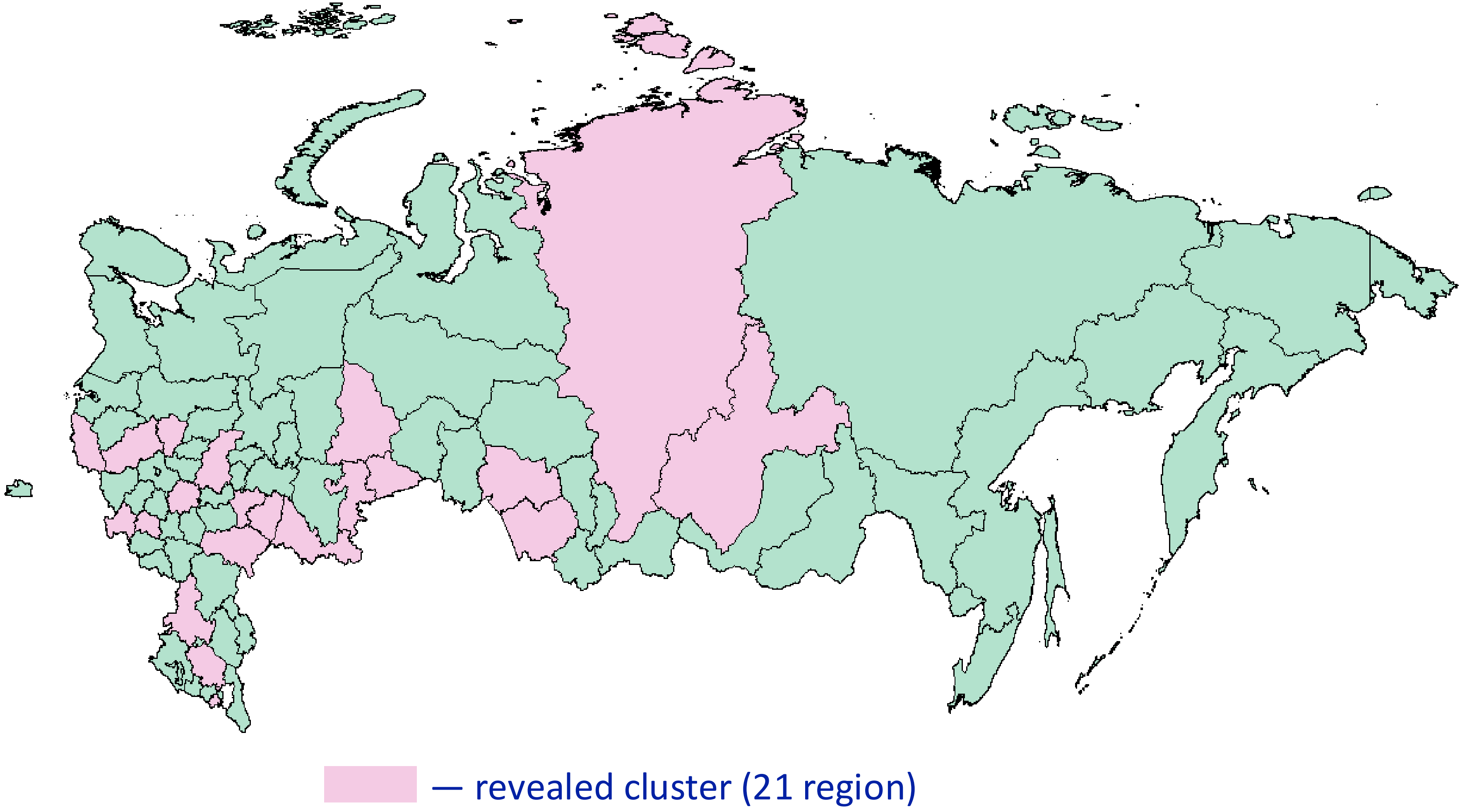
# REVEALED CLUSTER, 2001-2021 (LCM)

| | Pool (revealed cluster with "+" effect, 21 regions, N = 84) | | | | Time FE (revealed cluster with "+" **effect**, 21 regions, N = 84) | | | |
|---|---|---|---|---|---|---|---|---|
| Initial GRP per capita, 10 thous. rub. | –0.322*** | –0.319*** | –0.324*** | –0.321*** | –0.245*** | –0.245*** | –0.248*** | –0.247*** |
| | (0.032) | (0.033) | (0.032) | (0.033) | (0.037) | (0.033) | (0.034) | (0.030) |
| Investments in fixed assets, as % of GRP | 0.031 | 0.030 | 0.024 | 0.023 | 0.080** | 0.079** | 0.077** | 0.077** |
| | (0.022) | (0.021) | (0.023) | (0.023) | (0.032) | (0.031) | (0.034) | (0.033) |
| Employed people aged 50-59, % | –0.721*** | –0.726*** | –0.724*** | –0.728*** | –0.505*** | –0.514*** | –0.513*** | –0.519*** |
| | (0.046) | (0.043) | (0.043) | (0.040) | (0.069) | (0.071) | (0.071) | (0.072) |
| Employed with higher education, % | –0.134*** | –0.133*** | –0.134*** | –0.134*** | –0.108*** | –0.108*** | –0.108*** | –0.109*** |
| | (0.020) | (0.019) | (0.020) | (0.019) | (0.019) | (0.018) | (0.019) | (0.017) |
| Import of equipment, as % of GRP | | 0.041 | | 0.033 | | 0.030 | | 0.029 |
| | | (0.049) | | (0.046) | | (0.047) | | (0.047) |
| Internal R&D expenses, as % of GRP | | | 0.137* | 0.128* | | | 0.027 | 0.020 |
| | | | (0.071) | (0.071) | | | (0.064) | (0.066) |
| **Total ICT expenses, as % of GRP** | **0.472*****| **0.437***** | **0.331*** | **0.312*** | **0.347***** | **0.323**** | **0.323**** | **0.307*** |
| | (0.124) | (0.132) | (0.180) | (0.189) | (0.125) | (0.135) | (0.160) | (0.163) |
| Intercept | 22.275*** | 22.282*** | 22.542*** | 22.531*** | | | | |
| | (1.067) | (1.072) | (1.071) | (1.079) | | | | |
| Adjusted R2 | 0.886 | 0.886 | 0.888 | 0.887 | 0.350 | 0.345 | 0.342 | 0.337 |

*Notes: robust standard errors are in parentheses, *p < 0.1, **p < 0.05, ***p < 0.01*

# CLUSTER OF REGIONS WITH (+) ICT INFLUENCE

| Cluster of regions (N = 21) |
|---|
| Altai Krai |
| Bryansk Region |
| Irkutsk Region |
| Krasnoyarsk Krai |
| Kurgan Region |
| Nizhny Novgorod Region |
| Novosibirsk Region |
| Orenburg Region |
| Oryol Region |
| Pskov Region |
| The Republic of North Ossetia |
| Rostov Region |
| Ryazan Region |
| Samara Region |
| Saratov Region |
| Sverdlovsk Region |
| Stavropol Krai |
| Tver Region |
| Ulyanovsk Region |
| Chelyabinsk Region |
| Yaroslavl Region |



# MAIN FINDINGS

- The estimated effect of digitalization on the full sample of Russia's regions is negative
- After applying the LCM, which takes into account the heterogeneity of coefficients in the model, and the division into clusters, the effect becomes positive and varies from 0.3 to 0.5 for the revealed cluster of regions
  - is consistent with a review of the results from previous works [Vu et al., 2020]
- The obtained estimates of the impact of population ageing, as well as standard growth factors, are consistent with economic theory, but also require an analysis of possible heterogeneity

# THANK YOU
# FOR YOUR ATTENTION!

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# APPENDIX: LATENT CLASS MODEL (LCM)

Consider finite mixture models with $K$ components (Leisch, 2004):

$$h(y \mid x, \psi) = \sum_{k=1}^{K} \pi_k f(y \mid x, \theta_k)$$

$$\pi_k \geq 0, \sum_{k=1}^{K} \pi_k = 1$$

where $y$ — dependent variable with conditional density,

$h, x$ — vector of independent variables,

$\pi_k$ — the prior probability of component $k$,

$\theta_k$ — the component specific parameter vector for the density function $f$,

$\psi = (\pi_1, , \ldots, \pi_K, \theta_1', \ldots, \theta_K')'$— the vector of all parameters,

$\theta_k = \left(\beta_k', \sigma_k^2\right)'$.

# APPENDIX: LATENT CLASS MODEL (LCM)

The posterior probability that $(x, y)$ belongs to class $j$ is:

$$\mathrm{P}(j \mid x, y, \psi) = \frac{\pi_j f\left(y \mid x, \theta_j\right)}{\sum_k \pi_k f(y \mid x, \theta_k)} \quad (2)$$

The posterior probabilities can be used to cluster data by assigning each $(x, y)$ to the class with maximum $\mathrm{P}(j \mid x, y, \psi)$, $f(\cdot|\cdot, \theta_k)$ – mixture components (classes) and the groups in the data induced by these classes are clusters (Leisch, 2004).

The log-likelihood of a sample of $N$ observations is given by

$$\log L = \sum_{n=1}^{N} \log h(y_n \mid x_n, \psi) = \sum_{n=1}^{N} \log\left(\sum_{k=1}^{K} \pi_k f(y_n \mid x_n, \theta_k)\right)$$

# APPENDIX: LATENT CLASS MODEL (LCM)

The method for ML-estimation of the parameter vector $\psi$ is the iterative EM algorithm, which includes:

- estimate for each $(x, y)$

$$\hat{p}_{nk} = \mathrm{P}\left(k \mid x_n, y_n, \hat{\psi}\right)$$

- using (2) and define the prior class probabilities as

$$\hat{\pi}_k = \frac{1}{N}\sum_{n=1}^{N} \hat{p}_{nk}$$

- maximize the log-likelihood for each class separately using $\hat{p}_{nk}$ as weights

$$\max_{\theta_k} \sum_{n=1}^{N} \hat{p}_{nk} \log f(y_n \mid x_n, \theta_k)$$

- the E- and M-steps are repeated until the improvement of $\log L$ falls under a threshold or the number of iterations reaches the maximum.