CENTER FOR MACROECONOMIC ANALYSIS
AND SHORT-TERM FORECASTING
Tel.: 8-499-129-17-22, fax: 8-499-129-09-22, e-mail: mail@forecast.ru, http://www.forecast.ru
Institute of Economic Forecasting Russian Academy of Sciences

Ecosystem models as a forecasting tool for high-tech industries (the case of the ICT sector)

Science and Technology Foresight

XIX April International Academic Conference On Economic and Social Development

Head of division, CMASF; Ph.D. (Candidate of Sciences) **D. R. Belousov**

Expert, CMASF **A. D. Gromov**

Report is based on results of research ordered by and conducted on behalf of the Internet Initiatives Development Fund (Agreement "ЕП 6/6-16", December 09, 2016)

1. Ecosystem Approach: Methodology

Ecosystem Approach

Ecosystem *is a system of interacting entities that share resources and transform them from one type to another. The entities of the Ecosystem interact within the system of environments. This interaction determines the nature of reproduction in that area and main quantitative parameters of its activities*

Properties

- Reproduction both the Ecosystem and its main participants
- Complex but relatively stable structure (set of entities with their own goals, boundaries, etc.). Existence of specific core (that sets the specific character of ecosystem)
- Interaction of entities with each other. Sharing of resources, transformation of some resources into other resources, emergence of chains
- Functioning of entities within environments and with environments
- Change over time both in terms of quantity (growth/decline) and quality/structure (dissociation/entry of new entities from/into the Ecosystem)

Opportunities for Analysis, Forecasting and Control

- Opportunity to analyze the effects of both direct (generation of demand) and indirect impacts on the ecosystem through development of specialized education, capitalization of development institutions, etc.
- Assessment of the consequences resulting from the change in the quality of environments (digital, entrepreneurial, etc.) for the development of ecosystem as a whole.

Entities

Attributes

- Ability to set own goals
- Existence of boundaries that allow to specify the participant of Ecosystem;
- Internal homogeneity (which is, at least, greater than between the entity and other participants of Ecosystem). At the same time, a participant of Ecosystem may have a composite structure, that is, it can be represented by one or more communities, corporations, agencies, etc.
- Interactions (resource sharing) between the participants, which allows to interpret the inclusion of participants into the Ecosystem, an analog of "food chains."

Composition

Mature ICT companies; ICT companies in early stages of their life cycle; development institutions; business accelerators and incubators; traditional companies outside ICT sector; retail trade, including e-commerce; financial institutions (except for development institutions); state; education system; population; external world

Environments

Attributes

- Universal nature of environment in which, to varying degrees, are immersed all participants of the Ecosystem
- Absence of ability to act as entity (environment is "something, in which are functioning the participants of Ecosystem")
- Indirect nature of impact made by environments on the functioning of individual participants of Ecosystem

Paradox of Environments

Participants of Ecosystem have their own ability to set goals and resources and are key elements of the Ecosystem. However, in general, their interaction only strengthens the participants due to mutually beneficial exchanges. By contrast, the environments aren’t the active party in the processes of interaction between the participants. However, it is the transformation of environments, both arising as a side, "entropy" result from the functioning of participants in the Ecosystem, or associated with their targeted actions, makes on them a profound impact ranging from the transformation of behavior to their complete dissociation.

Composition

Legal environment; *Socio-cultural environment;* *Digital environment;*

Business environment (business and innovation climate)
Infrastructures are interpreted as inhomogeneities in the environment, the analogs of "landscape."

Quantitative Analysis: Interaction Matrices of Participants of Ecosystem

From row to column	**Participant 1**	**Participant 2**	**…**	**Participant 12**
Participant 1		Flow 1.2	…	Flow 1.12
Participant 2	Flow 2.1		…	Flow 2.12
…	…	…		…
Participant 12	Flow 12.1	Flow 12.2	…	

Types of Flows:

Financial Flow Matrix:

Current expenditures (primarily, payment for goods and services in the area of IT, payment for educational services, wages of IT specialists, etc.)

Investments (R&D expenditures, equity instruments, debt instruments, etc.).

Commodity and Material Flow Matrix:

Commodity flows (mirrored to the cash flows of demand for products of specific entities)

Flows of ownership rights (mirrored to investment flows)

Flows of intellectual property objects (mirrored to R&D expenditures).

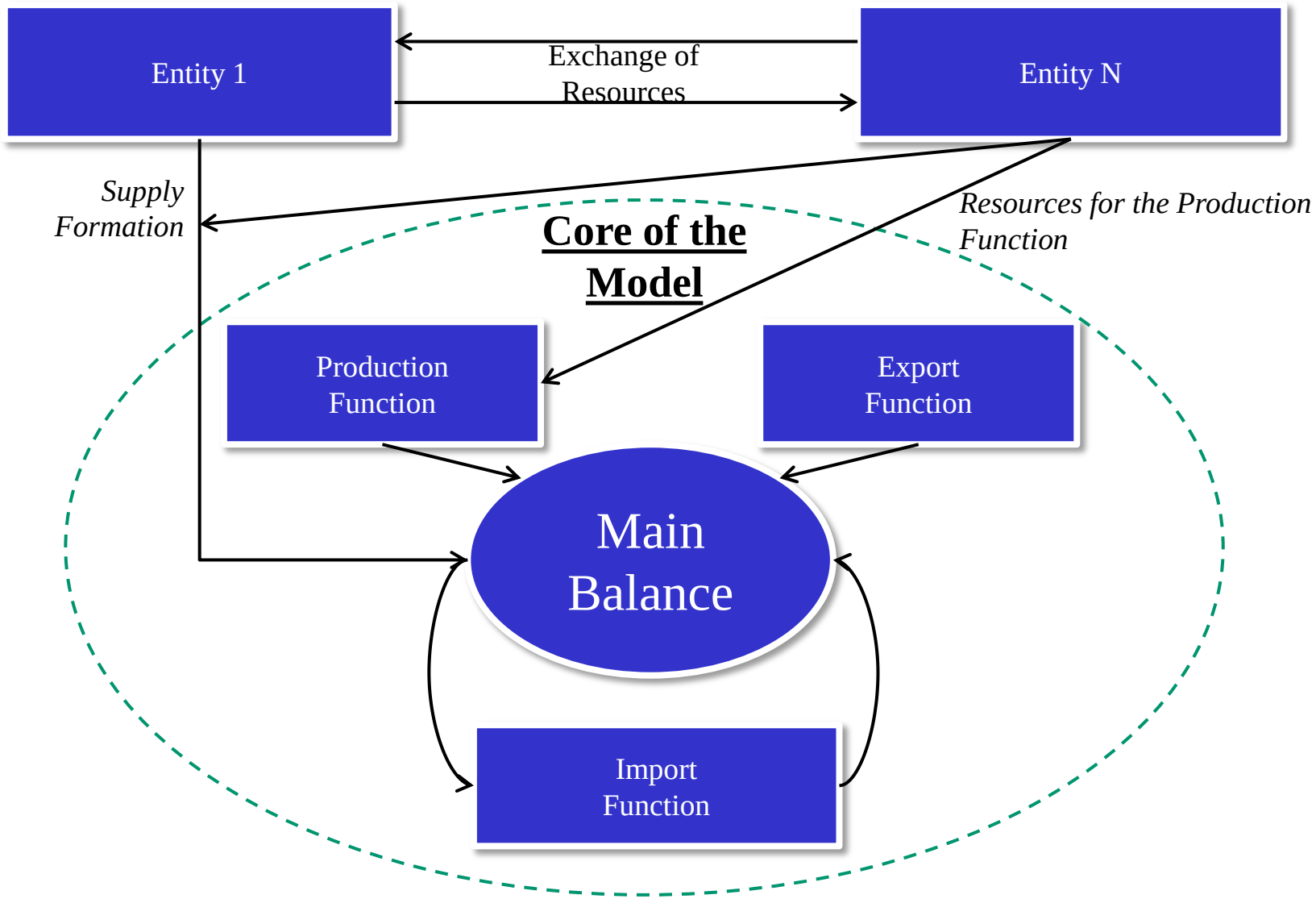
Talents Flow Matrix:

Human resources (transfers of IT specialists, inflow of students into the education system, hiring of graduates in IT specialties).

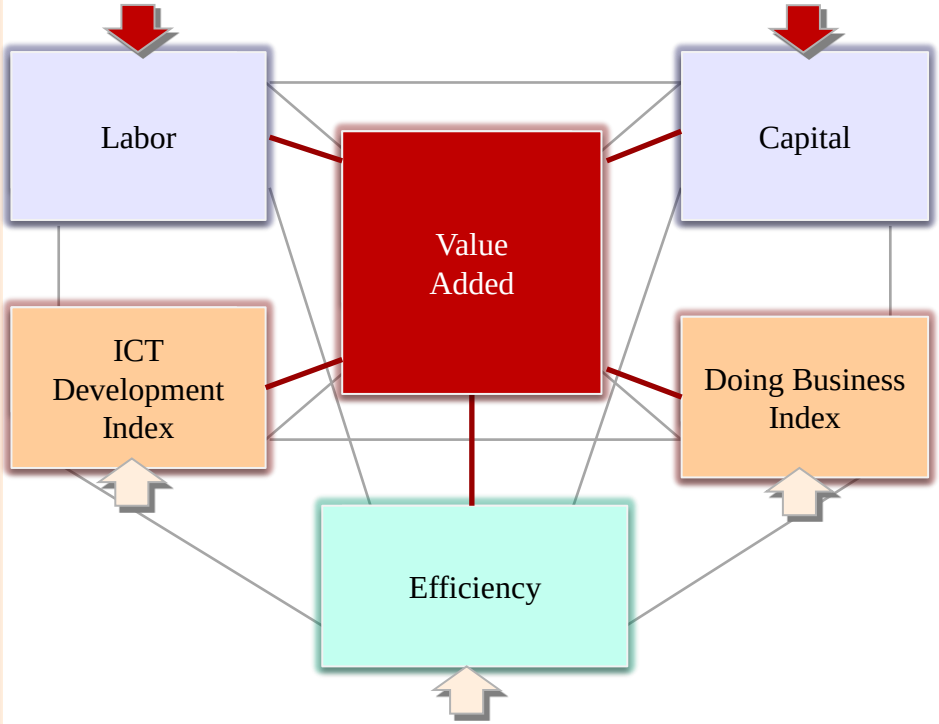
2. ICT Ecosystem Model

General Model Structure

Subjects of the Ecosystem, Periphery of the Model



Production Function of the Traditional ICT sector



Modeling Outcome in the Unit

- ✓ Value added
- ✓ Output (shipped products)

Value Added Model

- ✓ 3 groups of factors: factors of production, environment (*ICT development index as an indicator describing the development of digital environment; Doing Business index describes the quality of business climate and innovation*), technological development
- ✓ 2 types of contribution by the factors: direct contribution and contribution interrelated with other factors (in the form of pairwise works)
- ✓ Model Specification:

$$\log(Q\_\$VALUEADDED) = \beta_0 + \sum_{n=1}^{4} \beta_n \log(X_n) + \\ + \frac{1}{2} \sum_{n=1}^{4} \sum_{k=1}^{4} \beta_{nk} \log(X_n) \times \log(X_k) - u$$

Where $Q\_\$VALUEADDED$ is the value added produced by the companies in ICT sector, X are the factors of production, including 1) $N\_EMPLOYEES$ is the number of employees in ICT sector 2) $Q\_\$CAPITAL$ are total investments in ICT sector over 4 years in constant prices 3) $F\_ICTINDEX$ is the ICT development index 4) $F\_DOING\_BUSINESS$ is the Doing Business index

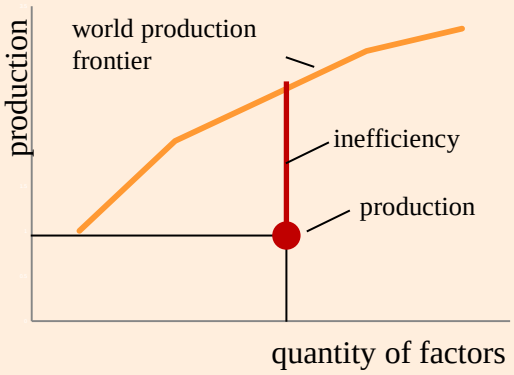
Output (shipped products) is modeled based on value added, assuming that the share of material costs in the output of ICT sector is constant.

Production Function of the Traditional ICT sector

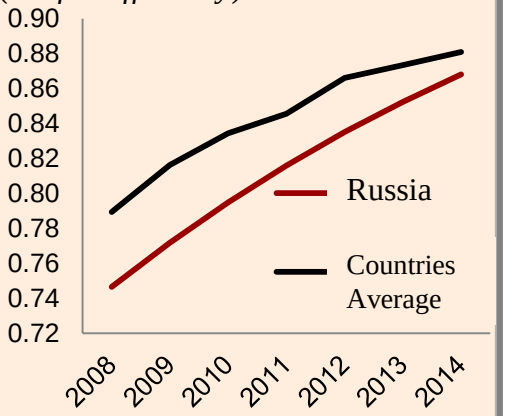
Margin of Inefficiency

The model is assessed by using stochastic frontier analysis. The margin of inefficiency reflects the difference between the maximum output that could be produced using available factors and the actual output.

Margin of Inefficiency Example



Efficiency Dynamics (1 – full efficiency)



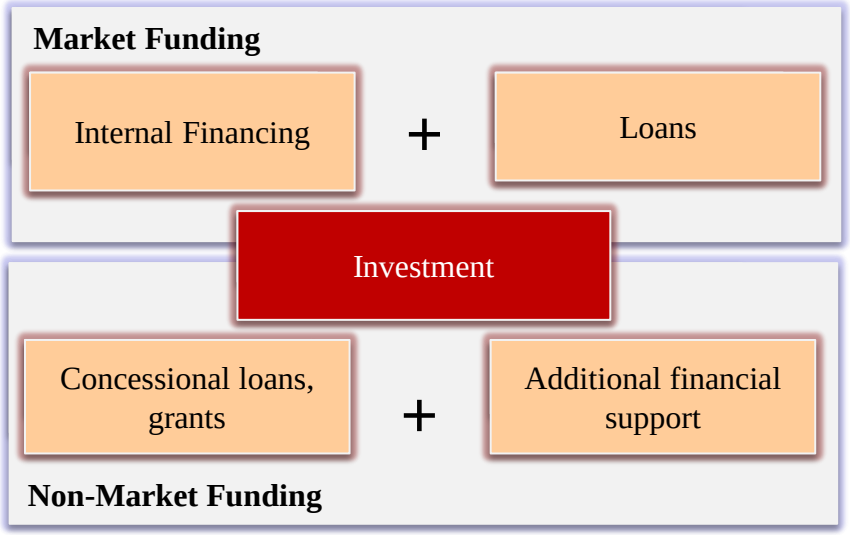
In the model, the margin of inefficiency is set between 0 (total inefficiency) and 1 (total efficiency). Total efficiency corresponds to the position on the world technological frontier of production.

ICT Development Index

The index describes the quality of digital environment and infrastructure that contribute to the development of ICT production. The values are in the range from 0 to 10.

Indicator	%
ICT access	40
Fixed-telephone subscriptions per 100 inhabitants	20
Mobile-cellular telephone subscriptions per 100 inhabitants	20
International Internet bandwidth per internet user	20
Percentage of households with a computer	20
Percentage of households with internet access	20
ICT use	40
Percentage of individuals using the Internet	33
Fixed-broadband subscriptions per 100 inhabitants	33
Active mobile-broadband subscriptions per 100 inhabitants	33
ICT Skills	20
Mean years of schooling	33
Secondary gross enrolment ratio	33
Tertiary gross enrolment ratio	33

Investment Estimation Unit



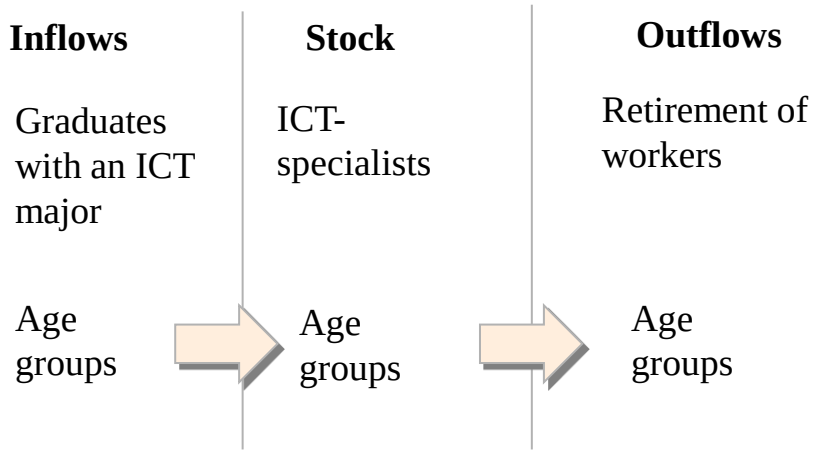
Market Funding Model

Factors that determine the growth rate of market investment in the Model:

- ✓ **Growth rate of value added in previous year**. Represents attractiveness of the sector for investors and the dynamics of the sector's internal funds, $\frac{Q\_\$VA_{t-1}}{Q\_\$VA_{t-2}}$.
- ✓ **Change of the weighted average rate of loans for enterprises.** Represents the cost of debt funding for enterprises, ΔF_RATE.
- ✓ **Change of share of non-performing loans in the banking system credit portfolio**. Represents the market risk and the banking system capitalization (with opposite sign), ΔF_NPL.

$$LOG\left(\frac{Q\_\$INV_t}{Q\_\$INV_{t-1}}\right) = 0.022 - 0.044 \times \Delta F\_NPL - \\ -0.013 \times \Delta F\_RATE + 0.380 \times LOG\left(\frac{Q\_\$VA_{t-1}}{Q\_\$VA_{t-2}}\right)$$

Labor Estimation Unit



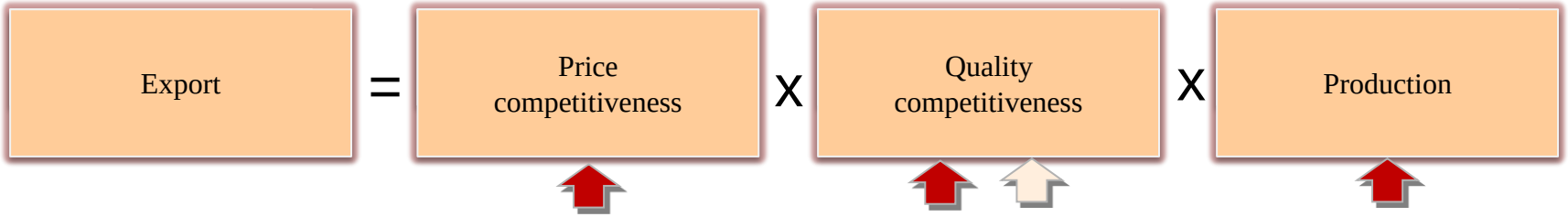
Exogenous variables

- ✓ Number of vocational education graduates with an ICT major.
- ✓ Number of higher education institutions graduates with an ICT major.
- ✓ Indicators of demographic forecast, by age groups (with one-year step).

Control variables

- ✓ Share of ICT-specialists working in the ICT sector (for large and medium size enterprises).
- ✓ Number of non ICT-specialists per one ICT-specialist in ICT sector.

Export of the Traditional ICT Output Unit



Export Model

- ✓ **Price competitiveness** is approximated by growth rates of real wages, which are the main component of production costs in the ICT sector, IQC_WAGE.
- ✓ **Quality competitiveness** is approximated by the indicator of relative investment activity, F_Inv_Act.
- ✓ **Production** is value added produced by the ICT sector, $Q\_\$VA$.

Relative Investment Activity

This indicator is calculated as the share of ICT sector fixed capital investment in the total volume of investment in the economy, divided by the cross-country average of this share.

Model

$$\ln(\text{Q\_\$EXPORT}) = -4.321 + 1.135 \cdot \ln(Q\_\$VA) + \\ + 0.298 \cdot \ln(F\_Inv\_Act) - 0.694 \cdot ln(IQC\_WAGE)$$

Import of the Traditional ICT Output Unit

Balance Method (Main)

- ✓ Internal use of ICT products
- ✓ ICT production export
- ✓ Volume of shipped products (negative sign)

Balance Check

If deviation between two estimations does not exceed 15-20% of the import volume, then the forecast is considered as being balanced.

Econometric Model (used for balance check)

Factor:

- ✓ Internal final demand for ICT products

Functions of Domestic Demand for ICT Products

Traditional Companies

- ✓ Based on cross-country comparisons of ICT capacity in various economic activities (using cross-industry balances by country)
- ✓ For each industry in leading countries, the study identified specific benchmarks that may or may not be exceeded depending on the logic of scenario.

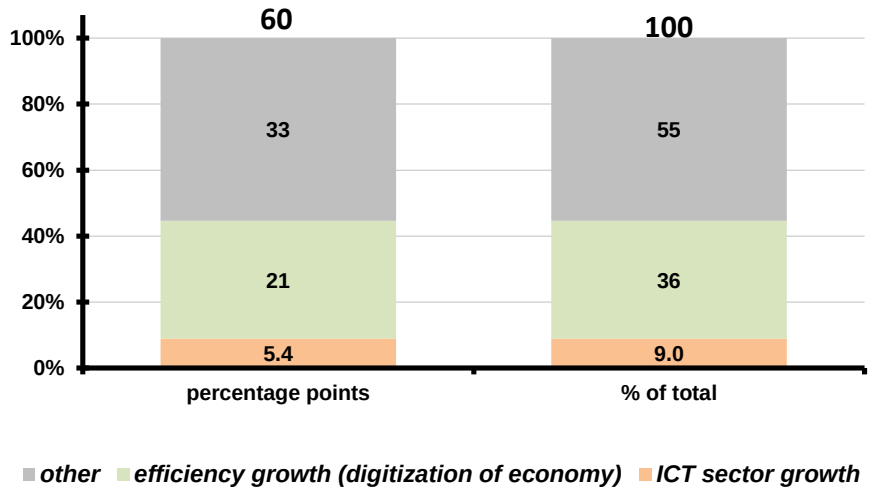
Modeling Demand in Individual Sectors

- ✓ Building Individual Empirical Models
- ✓ Using both in-house development parameters (mainly macroeconomic ones) and indicators of ICT sector development in Russia
- ✓ Trade, financial institutions, population, state
- ✓ The forecast of demand parameters for ICT products is used to directly relate the forecast of Ecosystem development with the long-term macroeconomic forecast. This allows to link the development of Russian ICT Ecosystem with the general dynamics of the economy (and, therefore, ensure the projection of domestic macroeconomic scenarios on the Ecosystem).

3. Certain Results of Estimation

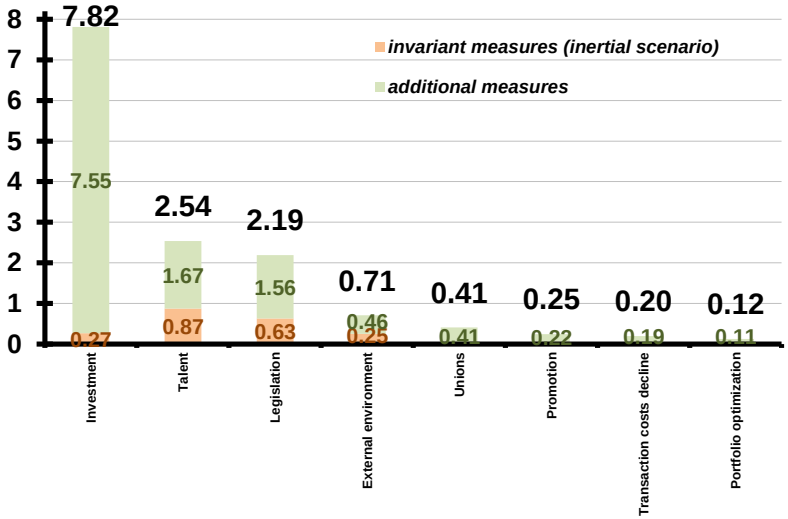
Indirect effects prevail over direct ones... but ICT investments are needed

Dynamics of value added in ICT and Russian GDP (growth rate, %), contribution of ICT to GDP growth in 2018–2030 (right scale, percentage points)



The direct effect of ICT on economic growth in the future period is small (only 9% of the economic growth) due to the sector size. At the same time, the indirect effect (through improved efficiency of the economy) is four times higher; in total, the digitalization can ensure conditions for almost half of GDP growth in the target scenario.

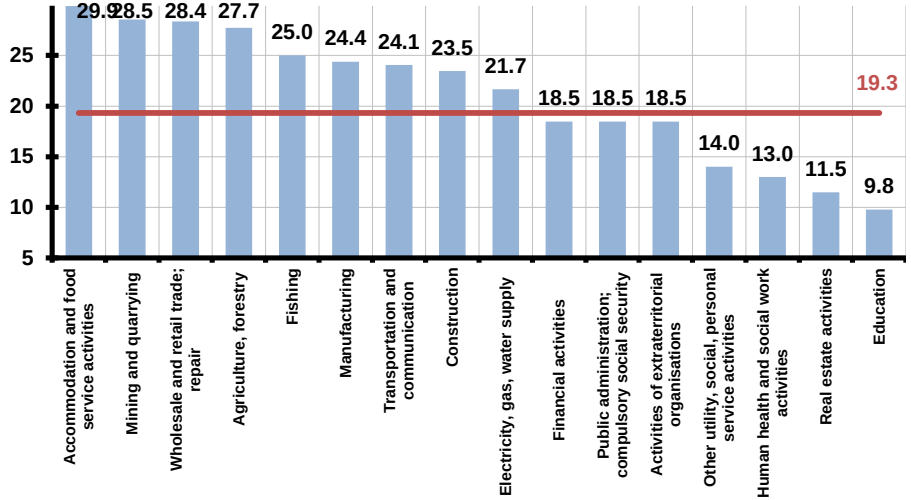
Contributions by the groups of measures to the output growth of ICT sector (target scenario), p. p.



A critical constraint to ICT development is the lack of capital across the system, including financial institutions. The other two bottlenecks, which are almost as large-scale in terms of possible effect, are indirect. These are the human resources potential and shortcomings in legislative regulation that constrain the development of markets.

Tangle of Social Problems: Risks of Economic Efficiency

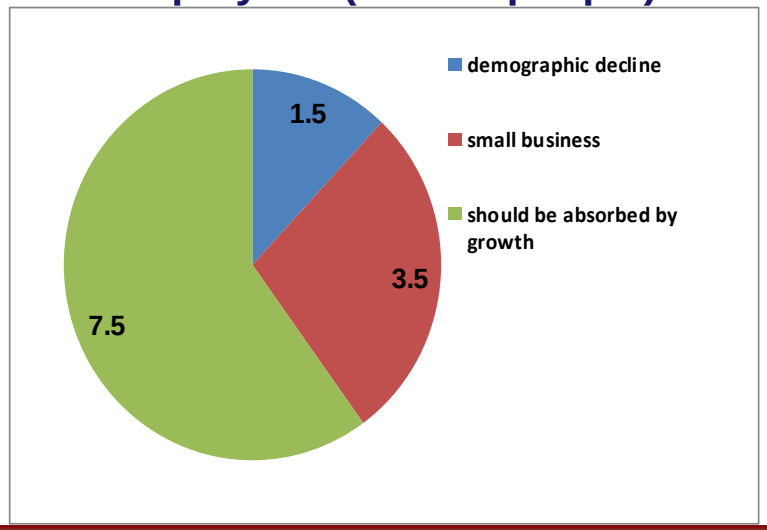
Increase in labor productivity due to digitalization (target scenario, 2018–2030, %)



Digitalization can ensure a two-to-three-fold increase in productivity…

…which could lead to employment redundancy at an unacceptable scale, unless it is transformed into expansion in domestic (through import substitution) or external markets

"Target" balance for use of redundant employees (million people)



Potential scale of employment redundancy (at a constant activity scale, thousand people in 2018–2030)