How Production Factors Affect Sustainable Development in a Region

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Abstract. The paper assesses how production factors affect the sustainable development of Yakutia, a Russian region. The function of sustainable development assumed here is the total shipments of the region’s administrative districts. The function of territorial arrangement of production has the following factors as variables: agglomeration, labor, capital, and infrastructure security. Analysis uses statistics on those factors over 2006-2017, operational data from sectoral ministries, and the 2002/2010 National Census data. The research applies integral assessment of the factors reduced to dimensionless values of 0 to 10 for comparability. Shipments are adjusted for inflation, with 2006 prices being used as the baseline. For price comparison, the value products shipped from industrial districts at global prices is adjusted for exchange rate fluctuations. The next step is to compute the coefficients of correlation between these factors and the total shipments with a breakdown by type: agriculture vs industry. A sufficient retrospective, an array of comparable data, and multiple correlation analysis have produced an output that is close to the actual situation in the region’s economy.

1. Introduction
Northern regions are hard to access, lack proper public utilities and other infrastructure, and have to survive harsh climate; all of this forces the local government and businesses to face a dilemma: to develop social infrastructure or to develop natural resources in rotations. This makes it important to assess how production factors affect shipments, an indicator of sustainable regional development. Other sustainable development factors (environmental status as a function of anthropogenic and technogenic impacts, entrepreneurship, market situation for the shipped products, etc.) are not taken into account in this research. The paper dwells upon the classic triad of land, labor and capital; the first factor is analyzed through the lens of infrastructure security and agglomeration factors. The authors hereof believe such interpretation of the production factors is scientifically significant because the today’s mining technologies are advanced and feature high performance, the natural resources are non-renewable, and there an urgent need to facilitate sustainable socioeconomic development of the traditional farming areas occupied by the indigenous peoples of the North.
2. Theory, methodology, and methods
The primary data collection method for making a database and structuring the research samples for further analysis is described in the author’s previous paper [20]. It should be explicitly noted that the sample now excludes the City of Yakutsk, as the region’s capital city has preferential conditions for socioeconomic development. The tables now divide the administrative districts into 14 industrial districts and 20 agricultural districts, as these two categories are not comparable in terms of shipment. However, Olyokminsky District, traditionally considered an agricultural countryside, is herein designated as an industrial district, as its own factory, OOO Neryungri-Metallic at the Tabornoye Deposit, has been producing up to three tons of gold per annum from 2002 to 2017.

Leontiev [19], Cobb-Douglas, Allen, and Solow production functions are applicable to companies and to sectoral economies. Granberg Local Economic Indices [7, p. 115] use three basic approaches to project the set of regional economic indicators:
– identify the basic indicator and record (or control) other indicators as constraints. In this paper, the resultant indicator is the total shipments in billions of rubles, while the production factors serve as constraints.
– perform multipurpose optimization by several indicators as a way to optimize the local economy;
– construct integrated (consolidated) socioeconomic indicators.

The analysis uses the first-approach algorithm and picks the maximum values of the selected indicators. After picking the maximum values the districts have for a specific factor, normalize the indicators by the formulas (1) and (2); calculate the integral estimate for each factor.

Normalization is done to reduce incomparable indicators to a dimensionless form using the formulas (1) or (2) [16].

\[
C_{ni} = \frac{c_i}{c_{max}},
\]

\[
C_{ni} = 1 - \frac{c_i}{c_{max}},
\]

where, \( C_{ni} \) is the normalized value (rank) of the \( n \)th indicator for the \( i \)th municipal district;
\( c_i \) is the original value of the \( i \)th municipal district;
\( c_{max} \) is the maximum value of the indicator in the total population of municipal districts;
\( c_{min} \) is the minimum value of the indicator in the total population of municipal districts;
If the value of the indicator has a direct positive effect on the district’s rank, use the formula (1) — the higher, the better. If the effect is inversely proportional, use the formula (2) — the higher, the worse. In case a district does not have any value in this or that indicator, rate it at zero.

The output is a calendar year-aggregated index of how production factors affect the district’s total shipment; the index is produced by adding up the integral indicators for all the four factors by the formula (3):

\[
e = \frac{\sum_{i=0}^{n} k_n c_i}{m},
\]

where \( e \) is the integral estimate, \( k_n \) is the weight of the \( n \)th indicator; \( m \) is the number of indicators; \( c_i \) is the value of the indicator for the \( i \)th municipal district.

Applying the formulas (1) and (2) enables not only ranking the districts; it also indicates the actual situation with the production factors in this or that district. Formulas by Kovalenko and Avtaikina (1), (2) are different from simple linear scaling formulas in the sense that the minimum indicator is not nullified, i.e. the \( c_i \)th indicator is only zero if it is absent.

The make shipments with breakdown by year comparable, it is necessary to account for inflation, exchange rate fluctuations, as well as the total shipment as a function of fluctuation. Companies that ship at global prices have their shipments increased by a weaker national currency, which is not undeniable. Questionable is the ratio of exchange rate fluctuations and currency inflation [10]. Economists have yet to develop a more or less reliable method to find such ratios.
Industrial districts of the Republic

| No. p/p | Industrial districts | Agglomeration factor $c_1$ | Labor factor $c_2$ | Capital factor $c_3$ | Infrastrucure factor $c_4$ | Total shipment, million RUR | x1-x1sr |
|---------|----------------------|---------------------------|------------------|---------------------|--------------------------|-----------------------------|---------|
| 1 | Aklansk | 23,56248 | 28,80756 | 10,15499 | 18,12122 | 12941,47 | 3,803165921 |
| 2 | Anabarsky | 3,773133 | 15,8854 | 26,85297 | 11,38656 | 5183,967 | -15,98617783 |
| 3 | Buhansk | 5,890756 | 17,30165 | 6,167999 | 12,94175 | 1146,537 | -13,86855537 |
| 4 | Verkhneolomsky | 3,392703 | 14,21233 | 11,68088 | 16,74137 | 624,0842 | -16,36660837 |
| 5 | Vilyuysky | 23,79393 | 21,3709 | 7,681147 | 22,35503 | 1257654 | 4,034619837 |
| 6 | Lensky | 28,35578 | 26,8527 | 17,52607 | 24,19313 | 4257531 | 8,596472859 |
| 7 | Mirminsky | 30,25924 | 37,0164 | 19,11244 | 24,9575 | 6567595 | 10,49992613 |
| 8 | Neryunginski | 30,64877 | 35,54037 | 12,16337 | 21,89679 | 2826597 | 10,88945801 |
| 9 | Nyurbinsky | 21,62554 | 18,91548 | 15,81049 | 17,51676 | 1969634 | 1,866224497 |
| 10 | Oymyakonsky | 15,10906 | 18,88379 | 13,97245 | 22,60533 | 5235833 | -4,650253568 |
| 11 | Olyokminsky | 18,06301 | 18,78289 | 5,762483 | 13,95278 | 3792657 | -1,696305869 |
| 12 | Tomponsky | 20,12857 | 18,16995 | 8,669882 | 16,80728 | 1557522 | 0,369254171 |
| 13 | Ust-Maysky | 19,50964 | 15,6404 | 8,617509 | 16,8354 | 1064648 | -0,249670665 |
| 14 | Khangalassky | 32,51776 | 22,43034 | 5,50767 | 26,87 | 2803039 | 12,75845025 |
| Average | 19,75931 | 22,1293 | 12,12003 | 19,08435 | 1379598 |

**Figure 1.** Shipments adjusted to the baseline (2006) for the inflation, ruble exchange rate fluctuations, and inflation as a function of fluctuations. *Author’s calculations.*

In this case, shipments in breakdown by year are made comparable for the agricultural districts by taking into account the accrued total inflation (apply the third line in figure 1); for industrial districts selling at global prices, comparability is achieved by applying a final adjustment coefficient (the seventh line). The figures in Line 6, Table 1 are approximate; they are rather intended to draw attention to the issue of comparability of indicators when analyzing shipments at global prices. When developing a more stringent method for finding the effects of exchange rate on the shipments from export-oriented regions, the adjustment coefficient in Line 6 might vary even more.

**3. Analysis of the results**

Having calculated the aggregate score for different years in terms of the four production factors, calculate the mean twelve-year scores. Reduce the shipments to the baseline prices of 2006 by applying the coefficients shown in Table 1. Also find the mean value of shipments over 12 years in million rubles, see figure 2. Since each indicator has been normalized to 0 to 10, the total normalized value for any factor is projected to tend to 40 when weights apply; the total for four factors thus peaks at 160. Figures 3 and 4 present the results of the first analysis with breakdown by sectors.
| District                  | Average 2006 | 2006 | 2017 | 2018 | 2019 | 2017-2018 |
|--------------------------|--------------|------|------|------|------|-----------|
| Allaikhovsky             | 3,759577     | 19,46119 | 19,61739 | 16,14032 | 192,3352 | -13,60945319 |
| Amginsky                 | 25,56571     | 23,12446 | 11,31599 | 19,7478 | 414,2206 | 8,19667923 |
| Verkhnevylyusky          | 23,30653     | 24,39967 | 10,15153 | 21,91323 | 434,7406 | 5,93750275 |
| Verkhoyansky             | 17,54035     | 24,56665 | 18,89778 | 18,70242 | 798,3156 | 0,171322873 |
| Gorny                    | 23,96084     | 21,64071 | 12,36745 | 17,10724 | 265,6149 | 6,59181226 |
| Zhigansky                | 15,26524     | 21,59711 | 20,61486 | 16,01801 | 162,17 | -2,103787752 |
| Kobyaysky                | 20,57752     | 21,04639 | 10,24859 | 16,59556 | 384,7932 | 3,208492252 |
| Megino-Kangalassky       | 34,58027     | 33,32693 | 10,92074 | 29,84665 | 691,5314 | 17,21124001 |
| Momsky                   | 8,354753     | 18,75165 | 17,54601 | 17,04439 | 211,0693 | -9,01427748 |
| Namsky                   | 30,45778     | 28,84108 | 10,15387 | 24,83005 | 392,7878 | 13,08874796 |
| Nizhnekolomsky           | 2,004521     | 23,0275 | 19,63308 | 19,3189 | 306,7532 | -15,36450986 |
| Olenebsky                | 9,72507      | 18,66343 | 23,98419 | 13,97297 | 292,2705 | -7,643960468 |
| Srednekolomsky           | 4,757035     | 17,03382 | 15,84229 | 16,34929 | 324,5446 | -12,6119952 |
| Tattinsky                | 20,74161     | 27,35364 | 11,8475 | 17,07692 | 751,3632 | 3,3725794 |
| Nizhnekolomsky           | 25,21534     | 22,70284 | 13,29776 | 19,73231 | 520,5136 | 7,846308083 |
| Churapchinsky            | 40,24191     | 32,56157 | 12,82818 | 21,1194 | 558,5489 | 13,05288012 |
| Eveno-Bytantaysky        | 11,49602     | 15,17338 | 13,89278 | 15,2427 | 71,52521 | -5,87301148 |
| Average                  | 17,36903     | 23,07316 | 15,57774 | 19,19719 | 431,7798 | 4,298492252 |

**Figure 2.** Aggregate mean score of production factors for Yakutian districts; mean yearly shipments in comparable prices. Data for 2006-2017.

Charts in Figures 3 and 4 use data for 2017, the last year of the covered period. When using this method, it seems more appropriate to analyze data of the last year to find out what the actual situation currently is.

**Figure 3.** Shipments in 2017 in 2006 prices; aggregate indices of production factors for 2017 for agricultural districts in Yakutia.
Comparing the charts reveals that agricultural districts are more sensitive to ups and downs in production factors; only have of the districts surpass the 50% (80/160) threshold of production factor availability in 2017. Production factors are apparently underutilized in Megino-Khangalassky, Churapchinsky, Namsky, and Gorny Districts compared to other districts.

For industrial districts, the chart in Figure 2 shows that having scored less than 40 out of 160 (or 25%), districts objectively face difficulties developing their industries. The chart also shows that production factors are underutilized in Neryungrinsky, Aldansky, Khangalassky, and Vilyuysky Districts.

Apply multiple correlation analysis to more accurately find the effect of factors on shipments and to analyze the data trends over 12 years; the analysis uses pairwise, partial multiple and multiple correlations in the context of all factors.

Pairwise correlation coefficients determine the effects of each factor on shipments; they are calculated by the formula (4) using data from Table 2.

\[ r_{yx} = \frac{\sum_{i=1}^{n}(x_{j,i} - \bar{x}) * (y_i - \bar{y})}{\sqrt{\sum_{i=1}^{n}(x_{j,i} - \bar{x})^2 * \sum_{i=1}^{n}(y_i - \bar{y})^2}}. \tag{4} \]

where \( r_{yx} \) are the coefficients of linear pairwise correlation of factors and shipments;

\( y_i \) is the total shipment of the ith district;

\( x_{j,i} \) is the jth factor for the ith district;

The following coefficients of pairwise correlation are thus obtained for industrial districts: 0.55 for agglomeration, 0.82 for labor, 0.49 for capital, and 0.51 for infrastructure. For the agricultural districts, the values are 0.45, 0.62, -0.09, and 0.59, respectively.

Partial correlation coefficients describe how each factor affects the shipments excluding the other three factors; these are calculated using the formula (5).

\[ r_{y|x_1,x_2,...,x_k} = \frac{r_{yx_1,x_2,...,x_k} - r_{y|x_1,x_2,...,x_{k-1}} * r_{x_1,x_2,...,x_{k-1}}}{\sqrt{(1 - r_{y|x_1,x_2,...,x_{k-1}})(1 - r_{x_1,x_2,...,x_{k-1}})}}, \tag{5} \]
Partial multiple correlation coefficients for industrial districts are as follows: 0.078 for agglomeration, 0.658 for labor, 0.62 for capital, and 0.11 for infrastructure. For agricultural districts, 0.137, 0.312, 0.316, and 0.197.

Total multiple correlation coefficients are calculated by the formula (6) using the calculated coefficients of partial multiple correlation.

\[ R_{y,x_1,x_2,...,x_k} = \frac{\Delta}{\sqrt{\Delta_y}}, \]  

(6)

Determinants of the matrices \( \Delta \) and \( \Delta_y \), used in (6) are calculated by the formulas:

\[ \Delta = (-1)^{k+1} \begin{vmatrix} r_{x_1,y} & r_{x_2,y} & r_{x_3,y} & r_{x_4,y} & 0 \\ 1 & r_{x_1,x_2} & r_{x_1,x_3} & r_{x_1,x_4} & r_{x_1,y} \\ r_{x_2,x_1} & 1 & r_{x_2,x_3} & r_{x_2,x_4} & r_{x_2,y} \\ r_{x_3,x_1} & r_{x_3,x_2} & 1 & r_{x_3,x_4} & r_{x_3,y} \\ r_{x_4,x_1} & r_{x_4,x_2} & r_{x_4,x_3} & 1 & r_{x_4,y} \end{vmatrix}, \]  

(7)

\[ \Delta_y = \begin{vmatrix} 1 & r_{x_1,x_2} & r_{x_1,x_3} & r_{x_1,x_4} \\ r_{x_2,x_1} & 1 & r_{x_2,x_3} & r_{x_2,x_4} \\ r_{x_3,x_1} & r_{x_3,x_2} & 1 & r_{x_3,x_4} \\ r_{x_4,x_1} & r_{x_4,x_2} & r_{x_4,x_3} & 1 \end{vmatrix}, \]  

(8)

The formula (6) is used to calculate the total multiple correlation coefficient for all the four factors and shipment, equal to 0.89 for industrial districts and 0.67 for their agricultural counterparts.

4. Conclusion

The relatively low effects of such factors of agglomeration, labor, capital, and infrastructure on the shipments in agriculture and industrial production as indicated by partial multiple correlation coefficients indeed corresponds to the actual state of the art in the region’s economy. The region’s agriculture has to survive in extremely cold air with low precipitation (236 mm/year on average) on permafrost in a place where the temperatures are positive for only 90 to 100 days a year. These limitations naturally affect the productivity of agriculture, a traditional business for indigenous peoples that requires governmental support. Agglomeration and infrastructure have low effect on industrial shipments, as oil-and-gas production is done in rotations and uses pipelines for transport; diamond and gold industries bear no extra exportation costs.

What makes this research novel is that it combines a variety of methodologies to find how production factors affect the shipments, which in turn are the primary indicator of the region’s sustainable development. The calculated multiple correlation coefficients for production factors indicate that the range of indicators needs to be expanded applicable to these factors; in addition, calculation should involve other factors that may significantly affect local production. The results also point to the necessity of a clearer and more diversified categorization of districts in terms of what their industries tend to specialize in.

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