Optimization of environmentally-oriented resource management

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Abstract. Environmentally-oriented natural resource management is associated with the concept of sustainable development, which is based on the balance of interests between economic industry development and ecosystem conservation that gives greater urgency to the task of considering the regional development and the effect of mineral extraction on long-term regional development. The research purpose is comparative analysis of the contemporary development trends of oil-producing regions. The research hypothesis suggests that depletion rate of non-renewable resources, if not supported by institutional mechanisms of stimulating economic regional growth, results in development of conditions for "resource curse" as evidenced by the dynamics of different socio-economic indicators of regional development. The research areas are Tomsk and Irkutsk Oblasts and Krasnoyarsk Krai. The research is based on the evaluation methods of mineral resource depletion (oil) allowing for necessary magnitudes of rental income re-investment as well as economic-statistical methods of socio-economic dynamics to reveal the trends of regional development. The research results have shown that the regions do not receive the necessary amount of investments for economic diversification. Tomsk Oblast is characterized by impressive demonstration of "resource curse", whereas Irkutsk Oblast is just at the early stage of that journey. The Krasnoyarsk Krai economy is more diversified. Calculation of socially dangerous depletion of oil reserves can serve as information for adequate justification of compensation approach towards sharing oil revenue taking into account re-investment of natural resource rent into socio-economic regional development.

1. Introduction

Environmentally-oriented natural resource management is associated with the concept of sustainable development, which is based on the balance of interests between economic industry development and ecosystem conservation [1]. The concept of natural capital is considered as an economic interpretation of sustainable development concept, which, from the viewpoint of scientific community, is realized by investment of incomes from non-renewable natural resources into human and fixed capital in the sphere of industry and infrastructure [2]. If natural capital is spent on current consumption, the region would be deprived of development perspectives after resource depletion. Particular attention should be paid to sustainable use of renewable resources of natural capital that creates the environment for development and reproduction of human resource assets. To solve this problem in one particular region is more complicated where mineral resource production prevails, especially energy [3].

The World Bank reports devoted to research in national wealth underlined that availability and use of oil recourses in some countries improved socio-economic conditions, whereas other countries, vice

versa, demonstrated decline of some other industries, reduction of population living standards, increase in unemployment etc. [4]. In scientific literature the theme of "raw material" or "resource curse" is a subject of considerable discussion [5]. In our opinion, one should agree with the authors' viewpoint expressed in critical review on "resource curse" on the fact that the key point of this question is to find out which factors have an impact on development pathway of resource-producing regions and how to avoid negative consequences of its focus on depleted resource extraction.

To tackle the adverse impacts of commodity dependence, a wide range of recommendations are offered, their meaning comes to the following principle points: diversification of economy to reduce dependence on natural resources and implementation of investment strategy, operation of stabilization funds. However, the effectiveness of interventions will depend on institutional environment in a country based on transparent and accountable government action [6, 7]. On the whole, it is worth noting that in Russia these approaches are implemented to various extents. Nevertheless, sharing oil revenues is not transparent enough. The national accounting standards do not reflect the process of resource depletion and allow for illusive conclusion that the state is getting richer, though it is actually getting poorer [8].

Socio-economic conditions in Russia are non-homogeneous. Moreover, there is a sharp polarization in regional development [9]. Therefore, regional approach is becoming more urgent, namely, the need for considering every region taking into account its specific features. One of the features is oil production, depletion of which is predicted within 25-50 years depending on its category. At present, only one way of preventing mineral resource depletion is considered. It is based on advance replacement of mineral resource base, i.e. exploration activities. However, in the light of the need for sustainable development concept there appears a question: up to what degree is it necessary to intensify exploration activities and oil extraction without a negative impact on the regional ecosystems [10, 11].

The authors of analytical report "Siberia and Far East in the 21st century: problems and perspectives of development" believe that the results of long-term forecasts for the next 15–30 years demonstrate the decrease in demand for hydrocarbons [12].

In addition, hydrocarbon economy development is limited by a number of existing international legal norms from the standpoint of sustainable development. Development of oil and gas industry is associated with considerable environmental and economic risks: low-carbon economy, hydrocarbon market volatility [13, 14].

It means that raw-material model of economic development based on super profits from natural resource export and their concentration in the federal budget does not work. The situation is aggravated by the fact that oil extraction in the region contributes to the growth of economic indicators (GRP, fixed capital investments) that promotes false ideas about economic performance. The evident consequences of the approach involved are budgetary shortfall in oil producing regions to provide investment policy, absence of true social development [12, 15].

This gives greater urgency to comparative analysis of the regional development trends in the current conditions and justification of "resource curse" in socio-economic development taking into account oil reserve depletion evaluation.

2. Materials and methods

The eco-economic approach in natural resource management primarily concerns adverse impact of oil and gas industry on the environment. At the same time, the long-term development strategies for oil-producing regions neglect the possibility of oil reserve depletion [16]. If mineral resource production has the large share in gross regional product and the period of commercial reserve production is less than 50 years, it is essential to calculate resource depletion by means of various approaches. The resource depletion index is rather low if the production period ranges from 30 to 50 years and the impact of diversified economy on the region development is insignificant [17].

The economic approach to estimating resource depletion is based on the assumption that reserves which are not completely depleted may be available to future generations. The longer the production

period is, the lower the resource depletion index is. The following estimation methods are commonly used:

- The user cost method developed by the World Bank relies upon calculation of the capital required for ensuring stable income after the depletable resource has been exhausted. The resource rent period and cash flow discounting are also considered.
- The net price method suggested by World Resource Institute to estimate depletion cost implies multiplication of specific rent by the changes in proved reserve volume. However, this method does not include such crucial aspects of economic assessment as the resource rent and discount rate. At the same time, it considers the replacement of fading reserves. It is used when annual reserve replacement is lower than the production rate [18].
- The present value method which is similar to the principles of UN Environmental-Economic Accounting reveals the changes in present value during the stated production period. The rental value is a basic parameter that may change [19].

This kind of analysis allows comparing the resource depletion index with the dynamics of socio-economic indicators and forecasting the development path of the region in the context of oil and gas production growth. The obtained results can be used for justifying the volume of investments which should be reinvested in the development of oil-producing regions.

Tomsk Oblast, Irkutsk Oblast, and Krasnoyarsk Krai, which are oil-producing regions of the RF, are the objects of the present study. The oil and gas production industry, mainly oil, has the largest share in the gross value added of these regions. The impact of oil production activity on the development of the region is analyzed in terms of economic, socio-economic, and environmental criteria. The predominance of the negative trends indicates an increased dependence of the region on depletable resource production, which results in unsustainable development. Therefore, special measures are required to prevent degradation of the region when the depletable resource has been exhausted.

This study presents the calculation of oil reserve depletion index in three oil-producing regions located in Siberian Federal District (SFD) and analyzes the impact of oil production activity on socio-eco-economic development of the regions. The data which are the bases of the present study are derived from the federal and regional statistics, websites of regional authorities, as well as national reports on the state of environment and natural resources of the entities of the RF [20, 21, 22, 23].

3. Results

Due to intensive development of oil and gas industry in Irkutsk Oblast and Krasnoyarsk Krai, over the past decades oil production has risen by the factor of 3.7 in Siberian Federal District. The fastest growth in oil production is registered in Irkutsk Oblast (figure 1).

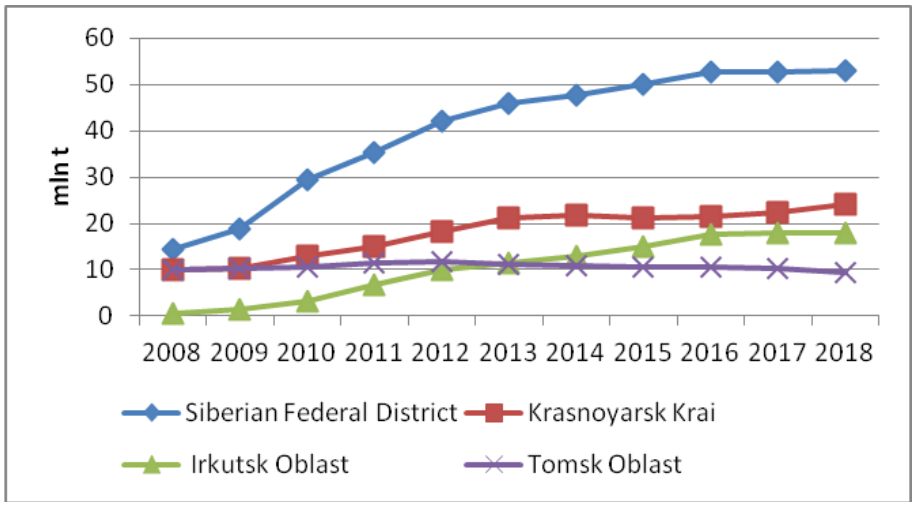

Figure 1. Oil production in Siberian Federal District.

Krasnoyarsk Krai is the top oil-producing region in Siberian Federal District accounting for 45% of total oil production. The share of Irkutsk Oblast is 34%, while Tomsk Oblast accounts for 18%.

The estimates of resources depletion relies upon the comparison of oil production rate and reserves increment through exploration (table 1).

Table 1. Oil reserve depletion (difference between oil production and reserves increment), mln tons.

Region/ year	2013	2014	2015	2016	2017	2018
Krasnoyarsk Krai	-2.4	67.2	11.2	-10.5	5.5	-3.3
Irkutsk Oblast	9.5	30.6	9.0	14.1	6.6	23.0
Tomsk Oblast	0.5	–1.9	–0.3	–5.5	-5.7	-7.8

Since 2016, Tomsk Oblast has seen a sharp decline in reserves increment. There has been a reduction of subsoil users' investments in exploration, precisely deep exploration drilling, since 2015. In Krasnoyarsk Krai, since 2018 there has been a decline in volume of oil reserves replaced through exploration efforts. In Irkutsk Oblast fading oil reserves are replaced with the fastest rates, however, the production period is only 17 years (table 2).

Table 2. Initial data for calculating oil reserve depletion.

Region	Reserves in 01.01.2019, mln t	Average annual production rate, mln t	Average annual reserves increment, mln t	years, T	Rent value in 2018, R, mln dollars	UR, dollar/t	Present reserve value, V_{t+1}, mln dollars
Krasnoyarsk Krai	851.8	24.0	21.2	35	5789.4	241.2	38210.04
Irkutsk Oblast	303.9	17.9	32.5	17	5384.7	300.8	32864.97
Tomsk Oblast	344.8	10.4	6.1	33	2076.3	199.6	13703.58

The results of reserve depletion calculations were compared using the described methods (table 3). The rent value was calculated on the basis of statistical data on profitability, market price within the extractive industry, and budget revenue from oil and gas production tax. The dollar's average exchange rate in 2018, i.e. 62.9 Russian rubles per 1 U.S. dollar, was the basis for calculation.

Table 3. Oil reserve depletion calculation, mln dollars.

	Reserve depletion	Tomsk Oblast	Irkutsk Oblast	Krasnoyarsk Krai
The user cost method	$U = R / (1+s)^T$	22.9	498.6	43.5
The present value method	$U_t = R_t – (s/(1+s))*V_t+1$	294.8	1115.3	822.1
The net price method	U=UR*(D-N)	1045.3	-	675.4

The lowest values of reserve depletion have been obtained on the basis of the user cost method. They reveal the minimum annual sum which should be invested in region development in order to provide the conditions for the industry that would replace the oil-producing one after depletable resource has been exhausted. The other way is to invest these funds into reserve replacement through

exploration activity regarding all environmental restrictions. The obtained result depends on the rent value and the production period, i.e. the shorter the production period is, the more funds are required to compensate future generation for the depletion of reserves. In Irkutsk Oblast the depletion index is higher than that in Krasnoyarsk Krai. It is explained by the fact that the oil production period is 2 times shorter. In Tomsk Oblast the depletion index is lower than that in Irkutsk Oblast despite the fact that the production period is longer. It is due to the lower value of the rent income which depends on oil production rate and industry profitability. The user cost method neglects the quality of the reserves, economical and geographical conditions of oil production. In Siberia, the average oil recovery index is 30%, therefore, the profitable period of oil production is 3 times shorter.

For the present value method, the calculations were made on the assumption that a 15% discount rate is constant during the expected lifetime of the reserve. The obtained results indicate the depletion of oil reserves, which may help in defining the portion of rent income that should be invested into the region development. For Irkutsk Oblast, the obtained sum exceeds one billion dollars. In case of Krasnoyarsk Krai it is 882.1 million dollars, which is due to the differences in the length of production periods.

The present value method was not used for estimating resource depletion index in Irkutsk Oblast where the activity in replacement of oil and gas reserves is higher than the present production rate. Tomsk Oblast shows the highest values of depletion index. This fact is explained by low activity in reserve replacement.

Table 4. Economic development indicators for oil-producing regions located in Siberian Federal District.

Indicator	Tomsk Oblast		Irkutsk Oblast		Krasnoyarsk Krai	
	2008	2018	2008	2018	2008	2018
The share of extractive industry in gross value added, %	35.4	27.6	4.5	27.2	4.4	21.2
The share of processing industry in gross value added, %	15.8	10.3	17.4	11.9	37.6	34.1
The share of extractive industry in fixed assets, %	22.4	33.9	3.6	16.2	6.3	26.2
The share of processing industry in fixed assets, %	9.5	7.1	14.6	12.2	14.2	11
New fixed assets across mineral extractive sector	51.4	42.8	8	37.3	11.3	38.2
New fixed assets across processing industry	10	14.6	13.3	13	21.3	10.7
The degree of wear of fixed assets in extractive industry, %	36.1	67.2	24.3	38	39.8	50
The degree of wear of fixed assets in processing industry, %	24.4	52.7	45.7	57.2	36.1	44.3
The share of completely worn-out fixed assets in extractive industry, %	9.1	32.6	5.9	7.7	11.2	19.2
The share of completely wear fixed assets in processing industry, %	5.8	15.9	15.7	21.3	10.5	17.1

The following indicators are essential in analyzing the development path of a region, its dependence on oil-producing industry and impact of oil production on social services, including the state of the environment.

The proportion of processing industry and extractive industry in gross regional product. The rise in oil production rate results in an increased share of extractive industry in gross regional product of Krasnoyarsk Krai and Irkutsk Oblast. In Tomsk Oblast, most oil fields have entered a final stage, and over the past decades the share of extractive industry in gross regional product has reduced by 7.8%, however, it is still the highest value (27.6%) among the discussed regions. At the same time, all regions witness a decline in the share of processing industry (table 4).

The correlation of investments into fixed assets in extractive and processing industries. Extractive industry receives significantly greater investments in the discussed regions. Tomsk Oblast demonstrates sharp differences in volumes of investments received by extractive and processing industries. In 2018, the investments into extractive industry are 3.4 times higher than that in processing industry. In Irkutsk Oblast, there has been a surge of investment in extractive industry since 2009, at the same time there has been the fall in investments in processing industry since 2014. However, the investment in processing industry increased in 2018. In Krasnoyarsk Krai extractive industry has received greater investments in the last two years alone (figure 2).

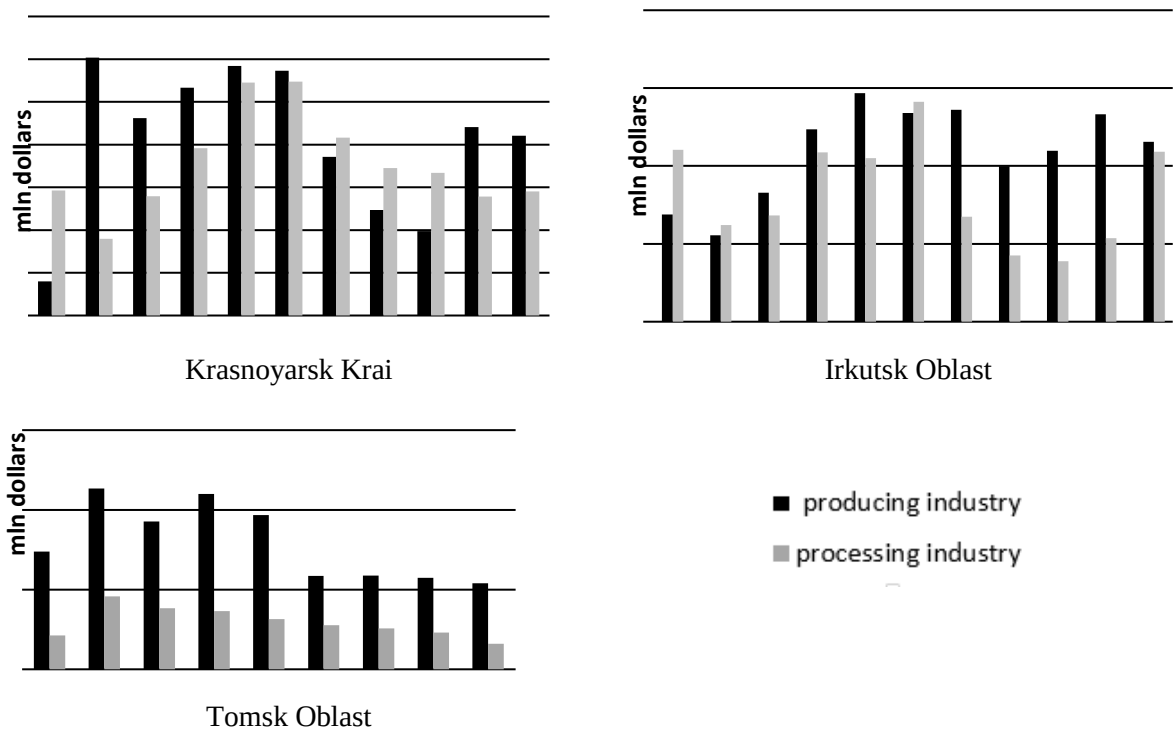

Figure 2. Investments in fixed assets in extractive and processing industries.

Dynamics of fixed asset value. In Irkutsk Oblast the share of new fixed assets in extractive industry has increased almost five-fold over the past 10 years, which, in its turn, has affected the value of fixed assets. The similar trends are observed in Krasnoyarsk Krai, which is the result of intensive exploration activity. There are opposite trends in Tomsk Oblast due to the decline in oil production. An increased wear of the fixed assets indicates the need for investments in extractive industry. In Irkutsk Oblast, the degree of wear of fixed assets has increased by 13.7%, and in processing industry – by 9.7%. As a result, the share of completely worn-out fixed assets has increased. In Krasnoyarsk Krai, extractive industry has been developing in the context of a large share of processing industry in

the gross regional product. Today, the share of processing industry is still significant. This reduces the risk for the region to become resource-dependent. However, there is a trend to decrease the share of processing industry. For comparison, in Tomsk Oblast the degree of wear of fixed assets has increased by 31%, and in processing industry – by 28.3% (table 4).

Dynamics of socio-economic indicators that characterize standard of living. The rise in oil production does not improve socio-economic conditions in Siberia. There is the fall in per capita gross regional product and per capita income as all oil revenues flow to the federal budget (figure 3).

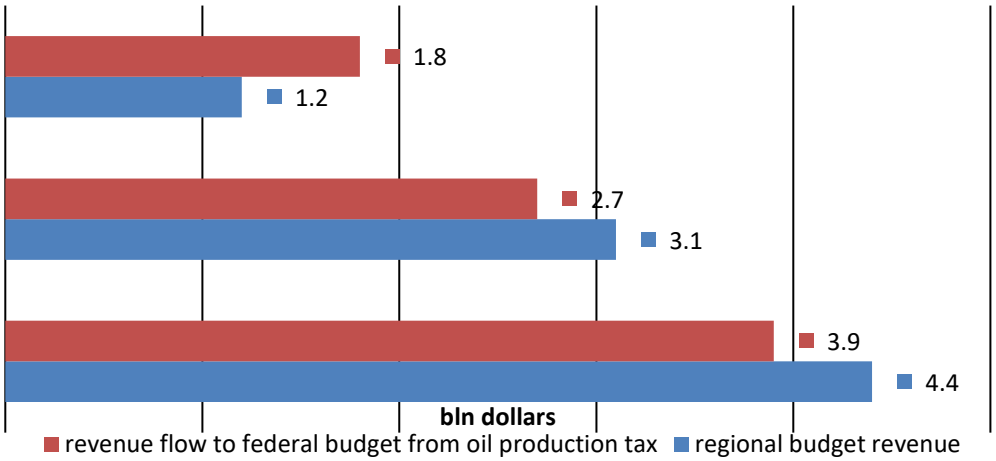

Figure 3. Revenue flows to regional budget and federal budget from oil production.

In Siberian oil-producing regions, the average per capita income is lower than that throughout Russia. It has declined over the past 10 years, leading to lower consumer spending. At the same time, the share of consumer spending in average per capita cash income has increased (table 5).

Table 5. Indicators of socio-economic development.

Indicator	Tomsk Oblast		Irkutsk Oblast		Krasnoyarsk Krai	
	2008	2018	2008	2018	2008	2018
Per capita gross regional product, dollars.	9653.6	8133.8	7039.7	8503.8	10267	11236.3
Budget revenue, mln dollars	1509.6	1182.4	3346.7	3078.4	6342.1	4404.1
Per capita income, dollars	1497.6	1097.9	1336	1228.9	2194.5	1523.9
Average per capita cash income, dollars	542.8	434.8	518	388.5	627.5	477.2
Average per capita consumer spending, dollars.	359.5	323.6	334.9	283.9	420.8	367.5
The share of consumer spending in average per capita cash income, %	66	74.4	64.7	73.1	67.1	77

The negative environmental impact of the oil and gas industry. According to the concept of sustainable development, the oil and gas industry is developed with due regard to sustainable ecosystem. The data on the negative environmental impact indicates high specific values per capita and per 1 mln of GRP, which are higher than average national values (table 6).

Table 6. Indicators of environmental impact.

Region	Air emissions from point sources (tons)		Discharge of pollutants into surface water sources (m^3)		Freshwater use (m^3)	
	per capita in 2018	per 1 mln rubles of GRP in 2017	per capita in 2018	per 1 mln rubles of GRP in 2017	per capita in 2018	per 1 mln rubles of GRP in 2017
The Russian Federation	0.12	0.23	89.5	175.3	360.8	706.9
Siberian Federal District	0.3	0.71	86.6	201.1	346.4	796.0
Krasnoyarsk Krai	0.81	1.26	106.1	162.0	664.6	1065.7
Irkutsk Oblast	0.27	0.55	219.8	442.1	384.1	722.3
Tomsk Oblast	0.22	0.51	22.3	47.0	353.8	759.3

The negative environmental impact in terms of air emissions is particularly significant in Krasnoyarsk Krai. The greatest amount of discharge of pollutants into surface water sources takes place in Irkutsk Oblast. It is also worth noting that the present paper does not consider the whole range of indicators reflecting the environmental impact of oil and gas industry. Today, when designing the exploitation play, the negative effect on the ecosystem is not taken into account [24]. Thus, according to the data provided by the researchers from Irkutsk Technical University as a result of the case-study of Yaraktinskoye, Markovskoye, and Dulismenskoye fields, the impact caused by drill cuttings on land resources is estimated at 9270.5 rubles per hectare [25].

4. Discussion

Tomsk Oblast can be regarded as a model region, where there are all above-mentioned evidences of "resource curse". In this region, the oil has been recovered since the 1970s, while other mineral resources (except for construction materials) are not produced. Moreover, currently there is a decrease in the amount of the oil recovered. The indicators of socio-economic development fail to improve and some of them are even lower than average national indicators. Over the past 20 years no big refineries have been built. In addition, the amount of tax paid for the recovered oil to the federal budget is higher than the regional budget. Meanwhile, there is a lack of investments to diversify the regional economy. It is also noteworthy that the current rate of the resource depletion will lead to sub-economic oil production in 10 years or even earlier if oil prices continue to fall [26].

In Krasnoyarsk Krai, one can observe well-balanced development of extractive and processing industries. However, investments in fixed-capital stock can be described with an upward trend in the extractive and a downward trend in processing, not to mention the decline of some socio-economic indicators, which makes it necessary to take urgent measures to balance the situation. The probable solution is to monitor the indicators of economic development and, when the level of oil depletion is within the range of 44-800 mln US dollars per year, to invest into industries which can substitute for the natural resource sector. It is vitally important to keep balance between economic sectors and to develop manufacturing industries, which are not directly connected with oil production.

Petroleum industry in Irkutsk Oblast is intensively developing, which also leads to the gap between the development rates of the extractive and processing sectors. The probable term of commercial reserves use is about 17 years. This trend can result in "resource curse" scenario, since the situation in the region in general reminds that in Tomsk Oblast. It is obvious that Irkutsk Oblast will follow the development trend of Tomsk Oblast if the intense development of petroleum sector hinders development of other industries. However, the high rate of resource replacement allows predicting the

situation when the term of reserves use is extended. To avoid the negative development trends, it is necessary to increase the investments in regional economy diversification.

According to the concept of sustainable development, the income obtained from non-renewable resources should be used to invest into the development of the area. If the regions follow the concept and spend the income obtained from oil recovery to compensate for resource depletion, the share of oil and gas production tax invested into the development of the area should be 21, 41, and 56% in Krasnoyarsk Krai, Irkutsk Oblast, and Tomsk Oblast, respectively.

Strategic planning of region development involves calculations of non-renewable resources depletion, as well as the analysis of natural capital in the region in general. The concept of natural capital implies assessment of ecosystem services with an opportunity to compare the results of particular resource management, for example, forest [27]. Virgin forests are becoming more and more valuable globally. The calculations provided in the previous studies indicated that in terms of their capacity to absorb carbon dioxide the value of Siberian forests is comparable (and in some regions is even higher) to that of mineral resources. Moreover, the role of forests in recreation can hardly be overestimated [28]. Thus, there are unique recreation resources in Irkutsk Oblast, which include World Heritage natural site Lake Baikal, where tourism industry can be developed [29]. According to the eco-economic assessments provided by the researchers from Moscow State University, ecosystem services within the area of Lake Baikal are estimated at 500-800 US dollars per hectare per year [30].

As one can see, distributing the income from oil production it is particularly important to take into account not only the trend in mineral resources depletion, but also the extraction of other natural resources, not to mention total degradation of the ecosystem. Current approaches to natural capital assessment based on the total economic value of nature imply a wide range of assessment methods, including non-market ones.

In our opinion, to ensure long-term sustainable development of oil-producing regions, it is necessary to introduce legislative measures, which will regulate reinvestment of natural resource rent into the development of the area and estimation of the amount of money spent on regional investment projects, as well as ensure tailoring approach to distributing the income obtained via extractive a depleting resource (in particular, oil) and environmental protection and remediation of the regional ecosystem.

5. Conclusion

This paper addresses the issue of interaction between the nature and society in term of the natural capital of the area under free market conditions. This is a new trend in economic geography allowing integrating the principles of sustainable natural resource management and green economy into the strategy of regional development, as well as improving environmental management under particular regional conditions.

Taking into account the concept of sustainable development and global trends and factors, which determine both perspectives and limits of Siberia development, one should admit that oil and gas industry plays a key role in the development of regional economy. Since the terms of oil production, as well as the resource itself, are limited, it is vitally important, within a short period of time, to lay a reliable oil-free foundation for long-term development of the region. Currently, the amount of the resource rent paid to the federal budget deprives the regions of financial resources.

The calculations on socially hazardous depletion of the resources can be used as provision for the rationale for applying compensation approach to distributing the income obtained from mineral resource production. When the processing industry is well-developed, the main goal is to keep the balance between processing industry and extractive industry, which is topical for Krasnoyarsk Krai. As for Irkutsk and Tomsk Oblasts, the investment in the area development and economy diversification should be three times as much as the current value.

The development of oil and gas industry implies the extension of the production site, which more often than not leads to total deterioration of the environment and degradation of the ecosystem. This means that renewable natural resources become limited and even non-renewable in some areas, when

"the point of no return" is achieved. The methodology of natural capital assessment allows estimating the full value of natural landscape and sites to improve natural resource management, thus considering the interests of the local society and protecting the ecosystem.

To ensure the sustainable development of oil and gas producing regions, it is necessary to design and provide the legal confirmation of the transparent mechanism of reinvesting the resource rent, which will compensate for the negative impact within the regional area.

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