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Scenario Forecast for Wind Turbine Manufacturing in Russia

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ABSTRACT

In this paper we suggest a method of evaluation of the prospects of creating and developing a wind energy-engineering sector in Russia, which is oriented, primarily, on domestic needs. Using the concept of learning curves as a framework, we evaluate the possible volumes of production of green energy equipment in Russia and prospects of competitiveness of such industries. Analysis of documents which determine the future development of Russian energy shows market share of Russian manufactures will be significantly lower than that of most wind energy equipment manufacturers, and wouldn't allow for a competitive level of costs and prices of Russian wind energy equipment. In the initial stages of domestic development of wind energy equipment, the average labor productivity may make up around 70-90% of the level of worldwide leaders, however this loss in productivity can be offset by tax benefits, which would stimulate entrepreneurs to localize their productions in Russia.

Keywords: Energy Equipment Machine-building, Productivity, Learning-by-doing Effect
JEL Classifications: O33, Q42, Q47, Q48

1. INTRODUCTION

World practice and numerous theoretical studies of last decades witnesses that in the current socio-economic conditions the ability to forecast the trends of technological development and adapt to them in a timely manner allows both individual companies and entire countries to achieve sustainable competitive advantage in international markets for innovation products and to attain leadership in the new technological order (Galtung, 1979; Perez, 1983; Freeman and Perez, 1988). On the level of national innovation systems (Lundvall, 1992) when emerging technologies lack commercial efficiency, governments play a crucial role in development of new industries not only by supporting private business, but also through targeted development of supporting sectors of economy (such as manufacturing equipment for new branches of the energy industry) and technical infrastructure (Schaper-Rinkel, 2013). Therefore, the problem of forecasting the development of priority economy sectors in the presence of a technological gap is one of the most relevant and difficult problems the science of innovation management has to face today (Robinson et al., 2013).

Nowadays the problem of forecasting and planning the technological development in Russia is solved only partially, at the level of isolated industrial branches and sectors, without accounting for the possibilities of interaction between developing sectors, considering the required increase in productive capacities or solving problems with the lack of skilled labor. One example is the energy development program, the main parameters of which are outlined in the "Energy Strategy of Russia until the year 2030" (Is. 11/13/2009, #1715-R). Projected parameters of the installed electrical energy capacity of Russia working on renewable energy sources can only be achieved by purchasing a substantial part of the necessary equipment abroad. For the "big" wind energy, the share of imported equipment is close to 100%, since the Russian manufacturers of energy equipment don't have the experience or technologies to serially manufacture wind turbines of high capacity (over 500 KW). However, according to the Energy Strategy, "the requirements of the fuel and energy sector need to be fulfilled mostly by Russian equipment by 2030. The share of imported equipment has to be below 12% after the first stage of this strategy is implemented, decreasing to 8% by the second stage and to 3-5% by year 2030. It is predicted that the Russian industry will master up to 95-98% of the energy sector product range." Since the first stage was designed to be implemented in 3 years, to ensure this rate of renewable power growth, Russia should be producing 600 or more wind turbines of high capacity (1.5 MW) yearly as of right now. Recent adjustments to the energy strategy pose somewhat less ambitious renewable energy targets, however they still intend to introduce 3600 MW of wind capacity and 1520 MW of PV capacity by 2020, produced mostly by Russian manufacturers (placing the value of the localization index for 2020 at 65-70%). That is, the forecasts and plans of economic development of individual branches do not match up, including branches that are closely connected to each other.

It is commonly assumed in the Russian literature that, due to the unavoidable (in the long term) change of technological orders in the power industry, the economic and political position of Russia in the world will greatly depend on how successfully the new branches of economy will develop, since they represent the "core" of the new technological order, and it will tell whether the country will be able to hold leading positions on the new energy markets or become a dependent importer (Tarasenko and Popel, 2015; Porfiriev, 2015). There are plenty of works dedicated to forecasting economic (most usually simply commercial) efficiency of new technologies in the energy industry (Sinyak and Kolpakov, 2014; Chernova et al., 2014; Fortov and Popel, 2014; Alkhasov and Alkhasova, 2014), however, the development of industries producing the required equipment doesn't receive enough attention. Besides the commercial efficiency of equipment production, the macroeconomic effects, such as the effect on the gross domestic product (GDP) and its structure, and the social aspects (employment, income, etc.) deserve more attention as well.

The research objective of this paper is developing a scenario-based method of evaluation of the prospects of creating and developing a wind energy-engineering sector in Russia, which is oriented, primarily, on domestic needs. The methodology of the research is based on the learning curve concept (McDonald and Schrattenholzer, 2001; Neij et al., 2003; Jamasb, 2007). Using this concept as a framework, we evaluate the possible volumes of production of green energy equipment in Russia and prospects of competitiveness of such industries.

2. METHODOLOGY OF FORECASTS OF DEVELOPMENT OF RUSSIAN ENERGY ENGINEERING

2.1. Market Share and the Average Labor Productivity in the Energy Equipment Manufacturing

Due to the technical and economic specifics of machine-building (energy machines included) as a science-intensive and high-tech branch of the industry, the profitability of enterprises in this industry is only possible with large sales and a significant market share. For industries like this, high spending on R and D and a noticeable learning effect help to decrease marginal costs while accumulating production experience (Capros and Vouyoukas, 1999; Nakichenovich et al., 1998; Messner, 1997). Because of this, with the growth of production scale, its net cost decreases significantly.

Therefore, there is a risk of becoming uncompetitive in the long term for Russian equipment manufacturers in new energy branches if they work only for the domestic Russian market. It is important for them to release their production to the global market. However, achieving a significant market share worldwide may be problematic, especially on the early stages of Russian energy equipment manufacturing's development. In order to avoid competitiveness, Russian manufactures of "green" energy equipment have to determine the entry level market share. The following model can be used for this purpose.

Let's consider a manufacturing of a certain equipment type, measuring production volumes in units. The qualification of an employee is considered to be equal to her/his labor productivity w (units per person per year in natural equivalent), or as APL = w·d (in cost equivalent), where d is the added value per unit of produce (that is, the difference between price and expenditures per unit), which is assumed to be a constant value for this model. Added value is preferable for this particular model over revenue or produced units per person since it considers high revenue with high expenses. Furthermore, one of the main indicators of the productiveness of a national economy, the GDP, is computed using added values of products created in the country. Thus, evaluating the labor productivity using added value we're also evaluating the input of this particular manufacturer in the GDP.

Besides natural labor productivity, let us introduce labor intensity of a unit of produce as $l=\frac{\eta}{w}$, measured in person-hours per unit, where η is the average fund of working time in hours per year. In science-intensive machine building, as well as many other high-tech industries, this value changes as experience accumulates, due to the learning effect. We're assuming that the change in labor intensity of a unit changes over time following a set of rules. As experience accumulates, the labor costs of the q^{th} unit of produce are reduced from their initial level of l_0 as follows (Alchian, 1963):

$$l(q)=l_0\cdot(1-\lambda)^{\log_2 q},$$

Where, λ is the learning rate. This is the most popular type of a learning curve used in simple models (logarithmic), which means that each time the experience doubles, the labor costs of a unit of produced are reduced by λ. Let us use the following approximation for the sum of labor costs (in person-hours) for Q units of produce, which is justifiable for the above logarithmic learning curve:

$$\sum_{q=1}^{Q} l(q) \approx l_0\cdot\frac{Q^a}{a}$$

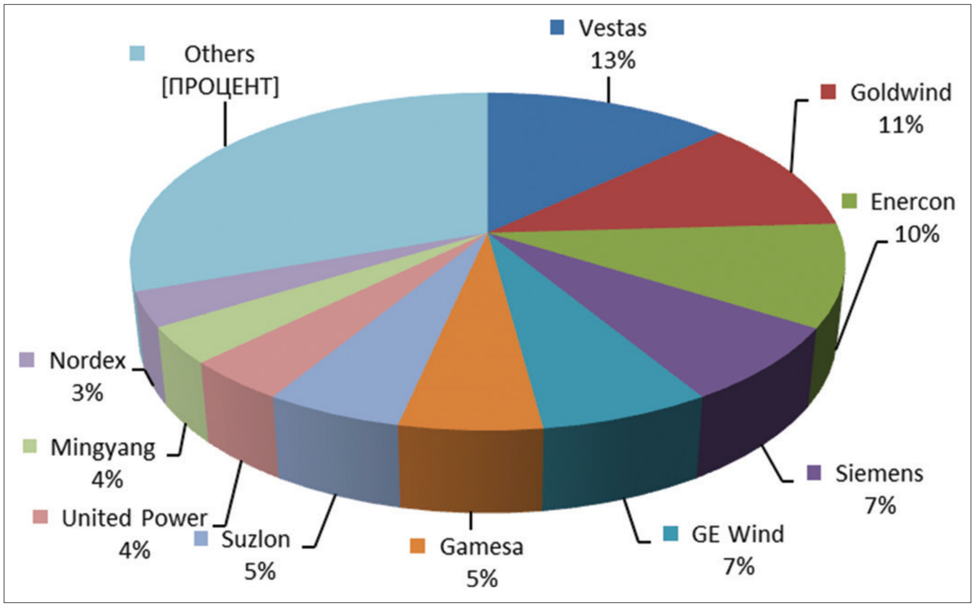
Where, $a = 1 + \log_2(1-\lambda) < 1$.

The average labor costs can therefore be evaluated as follows:

$$\bar{l}(Q)=\frac{\sum_{q=1}^{Q} l(q)}{Q} \approx l_0\cdot\frac{Q^{a-1}}{a},$$

Where, Q is the sum of all produce manufactured during the entire lifecycle. It's determined as Q =α Q_Σ, where Q_Σ is the total sales

Figure 1: The structure of the world wind turbine market in 2013 according to sales volume data



Source: Wind power monthly

volume for this type of produce during the lifecycle, and α is the market share for this type of manufacturing. Therefore, when the production volume increases x times, the total labor costs will rise by a factor of x^a, and average labor costs (both natural and in cost equivalent, considering a constant time-based payment) for a unit of produce will change by a factor of $x^{a-1}=x^{\log_2(1-\lambda)}$. That means they will decrease, since $\log_2(1-\lambda)<0$.

Summing up the above equations, one can deduce the average labor productivity for a company for the duration of the lifecycle:

$$APL=\bar{w}\cdot p=\frac{\eta}{\bar{l}(Q)}\cdot p=\frac{\eta\cdot d\cdot a}{l_0\cdot Q^{a-1}}=\frac{\eta\cdot d\cdot a}{l_0\cdot(\alpha\cdot Q)^{\log_2(1-\lambda)}}.$$

This equation indicates that the growth of global market share for a company causes a definite rise in average productivity, however, this process slows down overtime: $\frac{\partial APL}{\partial\alpha}>0$, but $\frac{\partial^2 APL}{\partial\alpha^2}<0$. This means that to increase the average productivity a big increase in market share is required, and the companies with smaller market share will suffer the most from productivity loss.

As a replacement for first unit's labor intensity (l_0) calculations may use average productivity of global energy machine building, APL_{global} (can be obtained from open statistical data). This model takes the value that is obtained with a global market share of 10% as the worldwide average labor productivity, that is, APL_{global} = APL(0,1). This productivity level is based in the structure of the worldwide wind turbine market in 2013-2015 (Figures 1-3).

In 2013, the leader of wind turbine manufacturers was Dutch Vestas with a market share about 13%, followed by Chinese Goldwind 11% and German Enercon (10%). In 2014, German Siemens took the top position with a market share 11%, with an American GE Wind and Vestas following as a second (about 10% each). In 2015 Golwind became a world leader with 13% of market share, as well as Vestas (12%) and GE Wind (10%), follow afterwards. Thus, the significant part of the wind energy equipment market consists of companies that take up 5-10% of the worldwide market with their current sales. Using the learning rate based on APL_{global} = APL(0,1), the labor intensity of producing a single unit can be reconstructed.

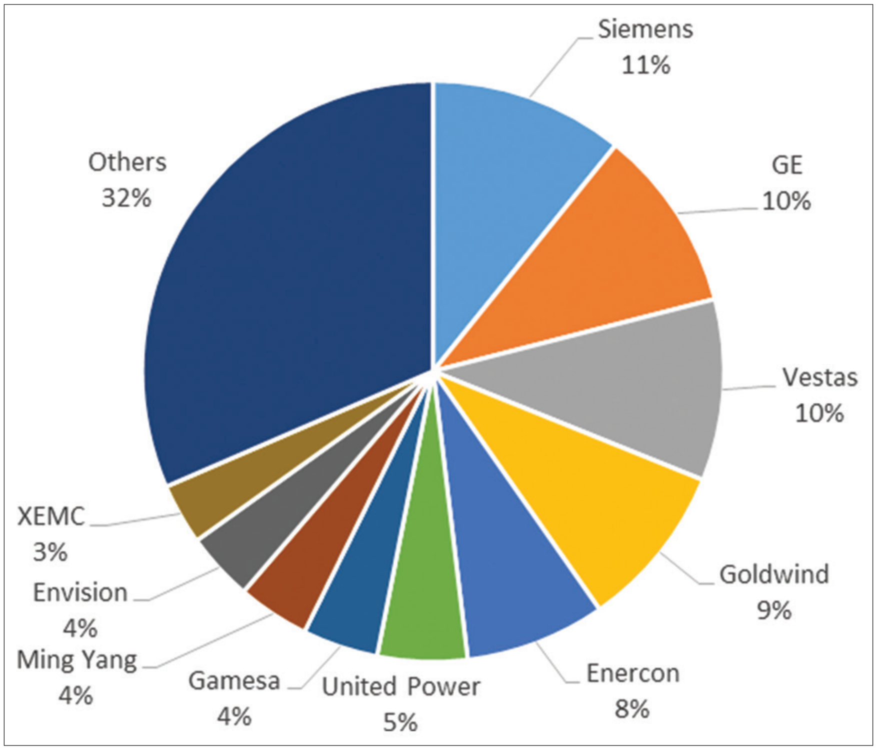
2.2. Forecasting the Volumes of Russian and Global Wind Energy Equipment Markets and the Possible Russian Market Share

According to the wind energy development forecasts of Global Wind Energy Outlook 2016, the overall increase of cumulative installed capacity worldwide as of 2020 (compared to 2015) will be in the range of 206,822 to 446,790 MW, depending on the scenario being considered (pessimistic or optimistic), and will reach 1,259,974 - 2,110,161 MW by 2030 (GWEC, 2016). Considering the material composition of this increase in capacity, this forecast means that during 2015-2020 the world manufactures should produce and install from about 103 to 223 thousand wind turbines (of 2 MW capacity average). During the period of 2020-2030, the necessary amount will be about 310-615 thousand turbines depending on the scenario.

In 2015, the overall capacity of manufactured wind turbines reached 58,889 MW[1], which can be approximated to 30 thousand turbines of 2 MW capacity. Thus, according to the pessimistic scenario of wind energy development there's no significant need for an increase in wind turbine market, besides the natural competition of global manufacturers and smaller companies for the increase of their market share. However, in order for the optimistic scenario to be possible, the global wind turbine market must increase more than twice before 2030.

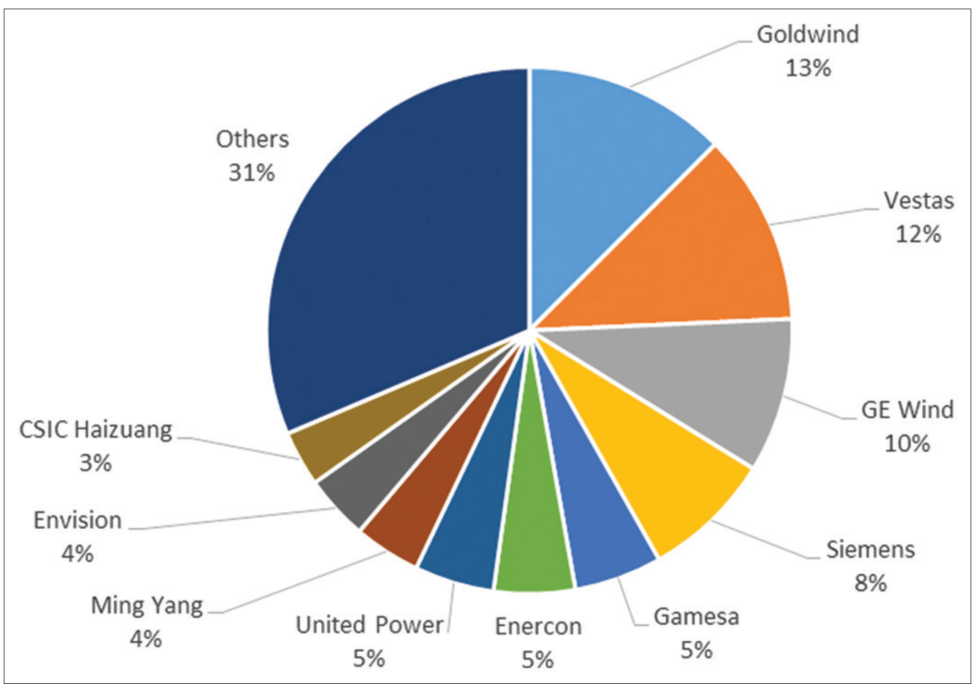
1 According to Gamesa annual report, company's sales in MWe in 2015 reached 3,180. Considering that market share of Gamesa in 2015 was 5.4%, world wind turbine market can be estimated as 58,888.89 MW.

Figure 2: The structure of the world wind turbine market in 2014 according to sales volume data



Source: Wind power monthly

Figure 3: The structure of the world wind turbine market in 2015 according to sales volume data



Source: Wind power monthly

Now let us view the issue of forecasting the development of wind energy in Russia in the framework defined by the governmental programs. The upcoming time period already has a set of target indicators for introducing wind energy capacities, defined by the aforementioned governmental decree "On introducing changes to the primary issues of governmental politics regarding the increase in renewable energy efficiency until 2020" (Table 1). It should be noted, that the plan for 2014-2016 was not implemented and targeted parameters were postponed for 2017-2020.

Long-term targets are defined in the "Russian energy strategy until 2030," which is currently being reviewed and modified to decrease the target indicators of the share of renewable energy from

Table 1: The limits of installed capacity for generating equipment in renewable energy

Object type/MW	2014	2015	2016	2017	2018	2019	2020	Total
Wind power plants	100	250	250	500	750	750	1000	3600

4.5% in 2030 to 2.5-3% in 2035[2]. To reach even these reduced renewable energy volumes until the end of the specified period (that is, 2035), it's necessary to introduce an overall generating capacity of 18 GW. Considering that the generating technology for wind energy is the most developed, and that Russia has plenty of territory with high-class winds, it's possible to assume that about a half of the planned increase in capacity will consist of wind energy installations. Thus, to provide the necessary growth rate, it's necessary to manufacture 1800 of 2 MW-turbines in the upcoming 3 years (about 600 yearly), and 225 such turbines need to be manufactured until 2035.

Thus, comparing the forecasts of the development of the global wind energy market and the Russian plans of wind energy development[3], it's possible to estimate the Russian market share on a level of 0.5-1%, depending on the scenario of wind energy development. The smaller market share corresponds to the optimistic development scenario, due to fixed absolute production values. How consistent is this market share with the competitiveness of energy machine building? As Figures 1-3 show, the global market consists mainly of companies with shares that are significantly larger than any expected value for Russian energy companies. This primarily means that the Russian energy equipment manufacturers can't possibly provide a production value that is comparable to that of global leaders, and thus are unable to set competitive prices. This, in turn, means that they cannot enter the global market, even if various regulatory problems would be solved. With a small sales volume, the production costs will be high, which will decrease demand of Russian energy equipment. At the same time, the target indicators for 2030 defined by the initial edition of the energy strategy allowed for competitive production volumes of wind energy equipment[4].

2.3. Analysis of Possibilities for Financial Stimulation of Localization for Innovative Production of Energy Equipment in Russia

Labor performance (measured here as added value per employee) defines ways to reward investors and employees themselves, as well as the possibilities of capital production. Proprietors of production factors have minimal threshold requirements to remuneration levels. An entrepreneur (private investor) creating production in a country or region will require their investments to be profitable. They will also need this profitability to be no less than the norm for this particular country, region or industry (accounting for country-specific risks). Employees, on the other hand, will require their salary to be no less than alternatives available to them, and so on. Is the attainable market share sufficient for the requirements of every private agent? Which conditions allow the state to coordinate their interests while achieving localization of production within the country that is practical from the macroeconomic viewpoint?

Let z_{req} be the minimal required remuneration rate of potential employees of energy machine building companies in a given industry and region, z_0 be the average remuneration rate in this region outside of the particular industry (usually, $z_{req} >> z_0$), k be the minimal required investment per employee per year (calculated as a capital-labor ratio with the current level of technology development and normative life time of fixed assets[5]), π_{norm} be the required normal profit per 1 employee per year (may also be defined as a share of k, that is, the minimal allowed investment profitability).

Then the condition of coordination of interests of employees and entrepreneurs may be formulated thusly:

$$APL \geq APL_{min} = z_{req} + k + \pi_{norm}$$

If $APL < APL_{min}$, that is, the average labor performance is not sufficient to provide necessary salary levels for employees and necessary normal profits for entrepreneurs, then this production will not be able to exist within the country, unless the state itself interferes. The employees will then have to accept the average salary in "other" industries, that is, z_0.

It is quite probable that a significant market share on the global energy equipment market won't be attainable for new and developing Russian manufacturers, at least in the short term. Therefore, a private investor will be uninterested in organizing this kind of manufacturing in Russia. Therefore, the state will not receive any tax payments from the employees or company owners, and employees themselves will not be able to receive salaries that are appropriate for a high-tech industry. Is it possible, then, that subsidizing the entrepreneurs to increase their profits to the minimal required threshold (at least via tax exemptions) will be less expensive than the losses from the lack of high-tech manufacturing and highly paid employees in the country? To answer this question, we need to calculate the lost income and other losses which are accounted for on a state level, such as the decrease of GDP, per employee, and compare that value to the change in labor efficiency in transition from a minimally required $APL_{min} = z_{req} + k + \pi_{norm}$ to the practically possible APL(α) with a realistic market share. If the social and economic loss from not having Russian manufacturers is higher than the difference of $[APL_{min} - APL(\alpha)]$ per potential employee, then it is reasonable for the state to consider tax exemptions for entrepreneurs on a level greater than or equal to that difference, thus providing them with the required normal profit.

2 Estimates obtained by analyzing the Russian energy strategy until 2035, which is currently being reviewed by the Ministry of Energy (http://minenergo.gov.ru/upload/iblock/621/621d81f0fb5a11919f912bfafb3248d6.pdf).

3 Let us view these forecasts as exogenous, without questioning the possibility of their implementation and resource requirements.

4 By 2030, introducing 90-130 GW of renewable energy capacity was planned. Assuming the leading role of wind energy, this would require manufacturing 500-2000 turbines yearly.

5 The average for all types of fixed assets can be assessed by comparing the depreciation or capital investments with a carrying value of fixed assets.

The suggested method of increasing investment attractiveness for the industry is fairly close to the so-called tax investment financing (TIF), which is a method of financing national and municipal investment projects through an anticipated increase in collected tax (Dye and Merriman, 2000; Craig and Joyce, 2001). When TIF-based projects are discussed, same ideas and calculation principles apply as with the suggested method of stimulating localization of machine building companies. However, TIF assumes that tax financing is done through the future growth of collected tax (Goodward and Gonzale, 2010), while the method suggested in this article uses long-term decrease in some taxation rates, which will bring an increase in collected tax in the short-term, if the manufacturing is successfully localized.

Formalizing the conditions of macroeconomic and budgetary efficiency of tax exemptions for entrepreneurs, let us set the tax rates for profit, property and the wages fund as t_{profit}, t_{prop} and t_{wag}, respectively. Then, without exemptions, the total amount of tax per employee will consist of $T=t_{wag}\ z+t_{prop}\ k+t_{profit}\ \pi$.

However, such a sum will only be obtained by the state if the manufacturing is located within the country. This, in turn, is only possible when $APL \geq APL_{min} = z_{req}+k+\pi_{norm}$. Otherwise, there will only be manufactures with smaller added value, which provide profits of $z_0 << z_{req}$, k_0 and $\pi_0 < \pi_{norm}$. Generally, the average labor efficiency for these alternative industries is usually several times below the norm for the high-tech industries, even with small market shares:

$$APL_0=k_0+z_0+\pi_0<<APL(\alpha).$$

Therefore, from the macroeconomic perspective (to be more precise, from the perspective of the GDP contributions), localizing the high-tech manufacturing is, without a doubt, beneficial. It is now necessary to pay attention just to its budget efficiency.

The volume of tax collected from "alternative" industries and activities is lower than from a localized high-tech manufacture (with a sufficient labor performance):

$$T_0=t_{wag}\ z_0+t_{prop}\ k_0+t_{profit}\ \pi_0<T_{loc}=t_{wag}\ z_{req}+t_{prop}\ k+1_{profit}\ \pi_{norm}$$

Is it possible to decrease tax rates to stimulate entrepreneurs to position this kind of manufactures in Russia? Let us introduce new tax rates with exemptions as t'_{profit}, t'_{prop} and t'_{wag}, respectively. Then, the total volume of collected tax becomes:

$$T'_{loc} = t'_{wag} \cdot z_{req} + t'_{prop} \cdot k + t'_{profit} \cdot \pi_{norm}$$

With the normal profit of $\pi = APL(\alpha)-k-z_{req}$ being lower than π_{norm} (if that wasn't the case, no stimulating measures from the government would be required). This incentivized tax value should be above the alternative sum of T_0 for the tax stimulation to be budget-efficient:

$T'_{loc}>T_0$ At the same time, entrepreneurs need to be interested in localized manufacturing. Originally, entrepreneurs would consider a normal profit of π_{norm} per employee with the existing tax rates, that is, they would actually agree to the net profit (excluding tax) of $\pi_{norm-net} = \pi_{norm}(1-t_{prof})-k\ t_{prop}-z_{req}\ t_{wag}$ per employee.

However, with tax exemptions, the actual normal profit $\pi=APL(\alpha)-k-z_{req}<\pi_{norm}$ will be taxed with T'_{loc}. Thus, the net profit per employee would become

$$\pi_{net}=\pi-T'_{loc}=APL(\alpha)-k-z_{req}-T'_{loc}$$

Entrepreneurs will become interested in localizing manufacturing if the following condition is fulfilled:

$$\pi_{net}>\pi_{norm-net} \text{ or}$$

$$APL(\alpha)-k-z_{req}-T'_{loc}>\pi_{norm}(1-t_{prof})-k\cdot t_{prop}-z_{req}\cdot t_{wag}$$

$$\Rightarrow APL(\alpha)>\pi_{norm}(1-t_{prof})-k(1-t_{prop})+z_{req}(1-t_{wag})+T'_{loc}$$

Let us note that the first three summands in the right side of the formula are equal to the average labor productivity that allows to fulfill the requirements of entrepreneurs and employees, that is, $APL_{min} = z_{req}+k+\pi_{norm}$, with tax excluded (no tax exemptions). The fourth summand, T'_{loc} (the sum of incentivized taxes per employee) with a localized high-tech manufacture, should be higher than the alternative T_0. Thus, one can substitute the right hand side of the entrepreneur interest condition with a smaller tax rate, while keeping the calculation valid:

$$APL(\alpha)>\pi_{norm}(1-t_{prof})-k(1-t_{prop})+z_{req}(1-t_{wag})+T_0$$

Replacing the "greater than" sign with a strict equality, we can find the threshold value of labor productivity which, with decreased tax rates, can stimulate entrepreneurs to localize this type of manufacturing, accounting for budget efficiency of this kind of tax exemptions:

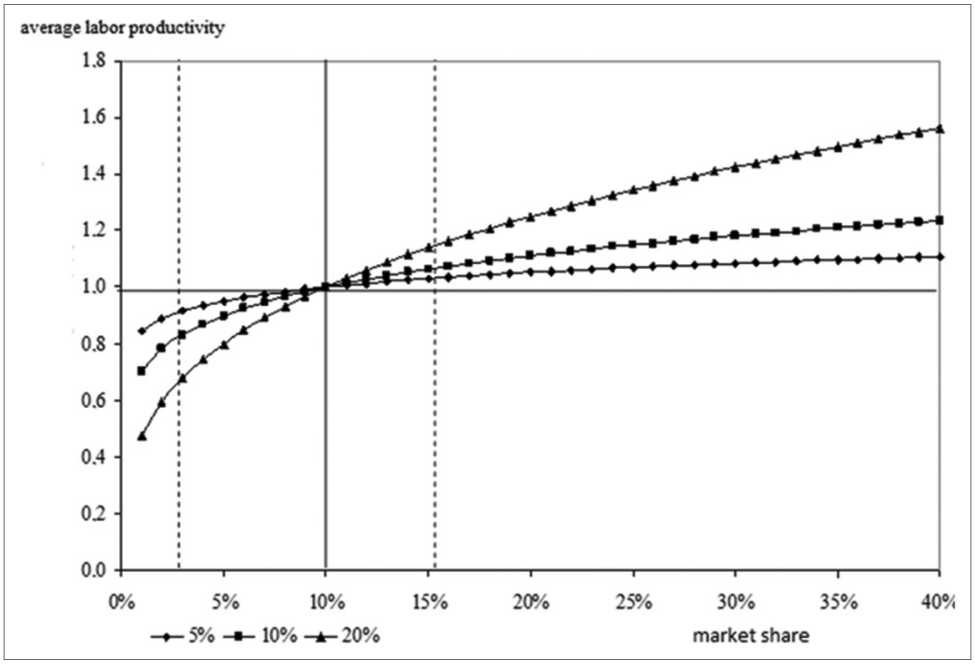
$$APL_{thres}>APL|\alpha_{thres}=\pi_{norm}(1-t_{prof})-k(1-t_{prop})+z_{req}(1-t_{wag})+T_0$$

Knowing the dependence of average labor productivity on the global market share, one can evaluate the minimal necessary market share of α_{thres} which still allows stimulating localization of manufacturing using tax exemptions, with such a policy being budget-efficient. This means that a flexible tax policy directed at localizing high-tech manufactures can be effective and possible to implement only if the loss in manufacturing being localized to foreign competitors isn't too high, that is, the existing global market share is not too low.

3. RESULTS

Figure 4 shows the effect of worldwide market share on average labor productivity in manufacturing companies. We calculate the ratio of labor productivity with a market share of α, defined as APL(α), to the global average of APL_{global} (which corresponds to a market share of 10%). The learning rate in manufacturing equipment for renewable energy sources (wind included) is still not entirely clear due to the lack of statistical data. The first statistical estimates in this fairly young industry show a learning rate of 10% for wind energy equipment (Schot, 1992; Liu et al., 2002; IRENA,

Figure 4: The effect of global market shares on average labor productivity



2012; Neij and Andersen, 2012). Therefore, Figure 2 shows three separate charts, for learning rates of 5%, 10% and 20%. The thin solid lines indicate the average global productivity level APL_{global} (horizontal) and the corresponding market share of 10%. The dotted vertical lines to the left and to the right of the $\alpha = 10\%$ line indicate the minimal (2.7%) and maximal (13%) market shares which correspond to manufacturers on Figure 1.

The Figure 4 shows that with slow learning rates of around 5% the productivity loss even for the smallest companies will be merely 20%, however, with faster learning rates of 15-20%, this value almost doubles. Smaller market shares for new manufacturers increase the strength of this effect further. Thus, if the market shares of Russian manufacturers of "green" energy equipment will be low, it will significantly increase labor costs per unit (2-3 times, given fast learning rates and a low market share of 1%), and similarly decrease the average labor productivity compared to the global level, especially compared to the worldwide leaders.

Charts on Figure 4 also show that with a 3% market share for Russian wind energy equipment manufacturers (assuming governmental manufacturing orders as specified in the Energy Strategy), the average labor efficiency will be between 68% (with a 20% learning rate) and 91% (with a 5% learning rate). This is an average global level, and it's consistent with a 10% market share. This loss to leading worldwide manufacturers could be theoretically compensated by tax exemptions for entrepreneurs.

Let us require the global average labor productivity level: $APL_{min} = APL_{world}$. For example, let the structure of added value for leading energy equipment manufacturers be such that $k = 0.1\ APL_{min}$; $z_{req} = 0.5\ APL_{min}$, $\pi_{norm} = 0.4\ APL_{min}$, with average taxation rates being $t_{profit} = 20\%$, $t_{prof} = 2\%$ and $t_{wag} = 30\%$. We also assume that the structure of added value in alternative industries is similar, but labor productivity is 3 times lower than in a high-tech manufacture.

Then,

$$APL_{thres}=0.4\ APL_{min}(1-0.2)+0.1\ APL_{min}(1-0.2)+0.5\ APL_{min}(1-0.3)+1/3(0.4\ APL_{min}\cdot 0.2+0.1\ APL_{min}\cdot 0.02+0.5\ APL_{min}\cdot 0.3)\approx 0.85\ APL_{min} = 0.85\ APL_{world}$$

That is, the maximal loss in average labor efficiency that can be compensated via tax exemptions without budgetary harm is 15% of APL_{world}. As Figure 4 indicates, the localized energy equipment manufacturers should have a 4-6% market share with a learning rate of 10-20%, and 1% of market share is sufficient for a 5% learning rate. As shown above, such levels are attainable even in the framework of satisfying domestic demand, without entering the global market. However, global reach is, naturally, desirable, which requires competitive products.

4. CONCLUSIONS

Using a concept of learning curves as a methodology framework, we evaluate the possible volumes of production of green energy equipment in Russia and prospects of competitiveness of such industries (on example of on-shore wind energy). A forecast of the production costs including the learning and scale effects is made. Quantitative ratings of these effects' value were obtained based on a statistical analysis of data on capital expenditures on wind projects from the report of the Global Wind Energy Council.

Analysis of documents which determine the future development of Russian energy shows that the volumes of renewable energy facilities (wind energy in particular) planned for 2030 would correspond to 0.5-1.0% of the worldwide market supply. This market share is significantly lower than that of most wind energy equipment manufacturers, and wouldn't allow for a competitive level of costs and prices of Russian wind energy equipment. On the other hand, the original version of the document targets conditions that are actually necessary for development of the domestic wind energy as a full-fledged competitive high-tech industry.

In the initial stages of domestic development of wind energy equipment, the average labor productivity may make up around 70-90% of the level of worldwide leaders. Technically, this loss in productivity can be offset by tax benefits, which would stimulate entrepreneurs to localize their productions in Russia. Furthermore, this policy of attracting high-tech industries can be effective both on macroeconomic and budgetary levels.

In some cases, it may be possible to use the methods suggested in the article to comprehensively evaluate the economic, social and fiscal effectiveness of certain measures (such as tax incentives) that increase the investment attractiveness of organizing high-tech innovative productions for "green" energy in Russia. The methodology suggested by this research allows performing forecasts of development of Russian energy engineering. Obtained results indicate that the market share that Russian manufacturers could count on in case a renewable energy program is implemented by the government is far smaller than that of global leading manufacturers of wind energy equipment and does not warrant a competitive level of cost and price for Russian wind energy equipment. In case a large enough market share (up to 10%) is reached, the work performance of Russian manufacturers on the early stages of development will be equivalent to 70-90% of the performance of leading global manufacturers. This loss can be compensated by tax benefits that stimulate entrepreneurs to localize the production in Russia.

The research results can be used to correct the state program for development of renewable energy and wind energy engineering.

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