OUTLINING THE FACTORS DETERMINING THE ECONOMIC EFFECTIVENESS OF COLLABORATIVE INTERACTION IN BUSINESS

Prof. Viktor Alekseevich Byvshev[1]
Prof. Dmitrii Vladimirovich Chistov[2]

Abstract: The purpose of this article is to explain the popular principle of collaborative business interaction by using the optimal firm size model developed by Oliver Williamson. A company that uses collaborative interaction reduces its production costs by lowering the price of its core capital.

The article is based on results from research conducted with budget funds under a government procurement awarded to the Financial University in 2014.

Key words: collaborative interaction, production function, production factors, optimal firm size.

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[1] Viktor Alekseevich Byvshev holds a doctoral degree in sciences and is a professor in the department of "Systems analysis and modelling of economic processes" at the Financial University under the Government of the Russian Federation, e-mail: vbyvshev@mail.ru

[2] Dmitrii Vladimirovich Chistov holds a doctoral degree in economics and is a professor in the department of "Applied Informatics" at the Financial University under the Government of the Russian Federation, e-mail: dchistov@fa.ru

1. Introduction

Over the last decade, the principal of collaborative business management has become very popular in the economy of the developed countries[3]. This principle refers to giving suppliers control over the majority of the specifications of created products, costs and innovations management[4]. An impressive example of organizing business activities in a collaborative network is the design and production of Boeing 787 Dreamliner by Boeing. While developing the airliner, the company stepped back from what was its key production competence and with the help of the Internet created a management system based on a globally distributed network of partners. Each member of the design team anywhere in the world at any time had the opportunity (within their established access rights) to see and check the drawings and models while a special application tracked the sequence and authorship of the changes imported in the project[5].

What is the economic benefit of collaborative interaction? This article aims at offering an answer to this question by applying the optimal firm size model. The main conclusion, based on the discussed model is as follows: when a company (for example, Boeing) applies the principle of collaborative interaction it works with numerous, qualified specialists who use their own resources (premises, computers, etc.). In this way, the company lowers the average value of its core capital and as a result reduces its production costs.

This article begins with a definition and a discussion of the popular optimal firm size model developed by O. Williamson, which is appropriate for the analysis of the goals set in this research work. After that, this model is modified by adding the production function when the company's revenue is being modelled.[6]

[3] See **Smorodinskaya,** N. V. Setevie inivvatsionnai ekosistemi i ih pol v dinamizatsii ekonomicheskogo rosta. Innovatsii №7, 2014, s. 27-33.

[4] See **Katukov,** D. V. Setevie vzaimodeistviya v inovatsionnoi ekonomike: model troinoi spirali. Vestnik Instituta Ekonomike RAN, №2, 2013, s. 112-122.

[5] See **Tapskott,** Don, Wilyams, Entoni, Vikinomika, D. Kak masovoe sotrudnichestvo izmenyaet vsyo. Best Business Books, 2009, s. 392.

[6] See **Klainer,** G. B. Proizvodstenaya funktsiya: teoriya, metodi i primenenie – M.: Finansi I statistika, 1986, s. 239.

2. Specification and analysis of Oliver Williamson's model of optimal firm size

Every organization, companies in particular, is an association of people (employees or agents) who work in collaboration to implement certain programmes (or goals) and act according to specified instructions. The objective of the company (trade organization, firm) is to generate profits. In order to do this, the company creates a specific hierarchical structure (the lower level employees are subordinate to the higher-level employees). What is more, in a company that is big enough, the optimal hierarchical structure usually consists of many levels[7]. Actually, the most widely spread type of hierarchical structure is the tree structure where the end – subordinates are situated at the lowest levels of the hierarchy while the top manager occupies the highest (first) level. The number of hierarchical levels will be represented by the letter n, the total number of employees by the letter N; the variable N will indicate the size of the firm.

The main managerial function of the hierarchy is to coordinate the activity of employees who specialize in the completion of particular tasks. Managers perform the managerial function and the realization of this function requires costs that increase simultaneously with an increase in the firm's size[8] even when the hierarchy of the firm is optimal. Is there an optimal size $N^*$of the firm that will maximize its profit (or any other utility function)? Research in the field of economics has discussed the optimal size of a firm for more than 80 years[9]. A review of the models related to this issue is presented, for example, in an article written by M.B.Gubko and N.A.Korgin in 2004[10]. Of all models described in the above-mentioned

[7] See **Voronin**, A. A., Gubko, M. V., Mishin, S. P., Novikov, D. A. Matematicheskie modeli organiziatsii.- M.: LENAND, 2008, s.259.

[8] See **Voronin,** A. A., Gubko, M. V., Mishin, S.,P., Novikov, D. A. Matematicheskie modeli organiziatsii.- M.: LENAND, 2008, s.259.

[9] See **Robinson**, E. A. G. "The Problem of Management and the Size of Firms," Econ. J., XLIV (June, 1934), pp.240-254.

[10] See **Gubko**, M. V., Korgin, N.,A., Novikov, D. A. Klasifikatsiya modelei analiza i sinteza organizatsionnih struktur. Upravlenie bolshimi sistemami. 2004. Bip. 6, s. 5 – 21.

publications, the most appropriate one with reference to analysing the effect of collaborative interaction, according to us, is the optimal firm size model. It was developed and outlined in the fundamental work by Oliver Williamson[11] and has not lost its importance and relevance. O. Williamson is the founder and most distinguished representative of the New Institutional Economics theory and was awarded the Nobel Memorial Prize in Economic Sciences in 2009.

This study offers a specification and an analysis of Oliver Williamson's model. It also presents a modification of the model through a more adequate modelling of the firm's revenues.

The Williamson model assumes that the firm's hierarchical structure consists of n levels. The variable n is a subject to explanation in accordance with the model, provided that the firm has maximum profit. The other variables of the model will be also discussed.

Exogenous variables of O. Williamson's model

1. The first exogenous variable is s, i.e. span of control; according to the author, this is the number of employees at the $(i+1)$ level of the hierarchy who are controlled by one employee from the i - th level of the hierarchy. For example, the top manager (the first hierarchical level) controls s employees $(s > 1)$ from the second hierarchical level. We would like to emphasise that at the n (last) hierarchical level are the bottom level employees. With the exogenous variable s we determine the quantity N_i of the employees at the i - th hierarchical level:

$$N_i = s^{i-1}. \quad (1)$$

2. The second exogenous variable is α, i.e. the level of compliance; according to O.Williamson, this is the fraction of work $0 \leq \alpha \leq 1)$ performed by a subordinate that contributes to the

[11] See **Williamson**, O. Hierarchical Control and Optimal Firm Size. //The Journal of Political Economy. 1967,Vol.75, №2, pp.123-138.

objectives of their superior. With this variable, O.Williamson actually tries to characterize the level of control in the organization. According to us, the importance of this variable is latent (hidden). We also think that it is problematic to put it in practice. For the purposes of the optimal firm size model, which we will develop in this article, we will not use the α variable.

3. The third exogenous variable is p, i.e. the price of the firm's output. The presence of this exogenous variable means that the firm produces a certain type of output, which obviously limits the model.

4. The fourth exogenous variable is w_0, i.e. the wage of production workers at the lower *n* – th level of the hierarchy.

5. The fifth exogenous variable is β. It represents the wage multiple between levels $\beta > 1$. Using this variable, we calculate staff wages at the i –th hierarchical level:

$$w_i = w_0 \cdot \beta^{n-i}. \quad (2)$$

The model's author challenges the adequacy of the model (2) with reference to data regarding General Motors and indicates the fairness of the non - equivalence $\beta < s$.

6. The last exogenous variable in the model is *r* - non-wage variable cost per unit output, i.e. the changing costs per unit of output that are not related to wages.

Endogenous variables of O.Williamson's model

1. N — the total number of employees in the firm (the amount of human labour L). Taking into account (1), this variable is determined according to the following formula:

$$N = L = \sum_{i=1}^{n} N_i = \sum_{i=1}^{n} s^{i-1} = (s^n - 1)/(s - 1). \quad (3)$$

Note that, based on (3), there are two approximations regarding the variable N:

$$N = L \cong s^n/(s-1) \text{ and } \quad N = L \cong s^{n-1}. \quad (3)'$$

2. C_L — costs paid by the firm for human labour. Based on (1) and (2), this variable is determined as follows:

$C_L = \sum_{i=1}^{n} w_i \cdot N_i = w_0 \cdot \sum_{i=1}^{n} s^{i-1} \cdot \beta^{n-i} = w_0 \cdot (s^n - \beta^n)/(s - \beta)$. (4)

Note that, based on (4) there is an approximation for the variable C_L:

$$C_L \cong w_0 \cdot s^n/(s - \beta). \quad (4)'$$

The author uses this equation in the process of specifying his model (see later in the text).

3. Q — the production of the firm (for a specified period of time). For this variable, the author accepts (Williamson, 1967, p. 128) the model:

$$Q = \theta \cdot (\alpha \cdot s)^{n-1}, \quad (5)$$

where θ — is a constant variable (the author states it equals 1 and this does not violate the scope).

Commentary 1. If we take into account the second approximation (3)′ and bring to mind the meaning of the exogenous variable α (level of compliance), then the meaning of model (5) becomes clear: level Q of the production is proportional to the amount of *useful* human labour in the firm. The analysis of these models allows us to conclude that it does not take into account the other production factors and most of all the level of the firm's core capital (we will designate it with the letter K). The lack of value for the firm's core capital in the production function for the level of production (5) is actually a prerequisite for the fact that the firm's size N does not depend on the level of the firm's core capital. It is difficult, however, to agree with this prerequisite. In addition, in the author's model (5) of the firm's production function, the marginal utility of useful labour does not depend on the amount of this labour. This contradicts the Gossen Law of diminishing the marginal utilities of production factors[12].

[12] See **Intriligator,** M. Matematicheskie metodi optimizatsii i ekonomi-cheskaya teoriya. - M.: AIRIS PRESS, 2002, s.202.

4. R — the author models the total revenue of the firm by using (5) based on the following equation:

$$R = p \cdot Q = p \cdot (\alpha \cdot s)^{n-1}. \quad (6)$$

5. C — represents the total variable costs of the firm; based on (4)′ and (5), the model of this value is:

$$C = C_L + r \cdot Q = w_0 \cdot s^n/(s-\beta) + r \cdot (\alpha \cdot s)^{n-1} \quad (7)$$

6. NR — is the net revenue; this value is determined on the basis of (6) and (7) by applying the following formula:

$$NR = R - C = p \cdot (\alpha \cdot s)^{n-1} - (w_0 \cdot s^n/(s-\beta) + r \cdot (\alpha \cdot s)^{n-1}). \quad (8)$$

We should note that equation (8) does not take into account the fixed costs of the firm. Therefore, we can identify the variable NR as *marginal net revenue.*

This concludes the discussion of the variables of O. Williamson's model. We must point out that the endogenous variable NR in this model is a function of all the model exogenous variables and the endogenous variable n, namely

$$NR = NR(n; s, \alpha, p, \beta, r, w_0). \quad (8)'$$

Determining the optimal firm size with the help of O. Williamson's model

According to Williamson's model (8), an optimal number of hierarchical levels in the company (n^*) means that the exogenous variable (n) has values that lead to maximum values for the firm's net profit (NR), provided that all other variables remain constant. If n is viewed as a continuous variable, the necessary requirement for the maximum of the firm's net revenue is presented as follows:

$$\frac{dNR}{dn} = 0. \quad (9)$$

By solving equation (9), we can first obtain the optimal number of hierarchical levels in the company n^* within the framework of O.Williamson's model of net revenue (8)

$$n^* = 1 + \frac{1}{\ln(\alpha)} \cdot \left[\ln\left(\frac{w_0}{p-r}\right) + \ln\left(\frac{s}{s-\beta}\right) + \ln\left(\frac{\ln(s)}{\ln(\alpha \cdot s)}\right)\right], \quad (10)$$

and then (by taking into account (3)), the firm's optimal size:

$$N^* = (s^{n^*} - 1)/(s-1). \quad (11)$$

Note that values (n^*, N^*), determined on the basis of (10) and (11) must be rounded to the nearest integer.

The analysis of (10) allows the author of this model to make the following conclusions.

1. The firm's optimal size increases when the level of compliance α in the company reaches 1. If the level of compliance in the company is $\alpha = 1$, the only reasons that limit its size, regardless of how big it is, are the decreases in the demand curve of the firm's production or the increases in the labour supply curve (the price of labour is higher at a determined level of its supply).

2. The optimal size of the firm diminishes because of the increase in the ratio $\frac{w_0}{p-r}$. Therefore, the optimal number of hierarchical levels is not big in the labour – intensive industry sectors.

3. The optimal number of hierarchical levels increases when the span of control s also increases. Conversely, the optimal number of hierarchical levels decreases when the staff wages multiplier β increases.

Commentary 2. The author's conclusion about the fact that when the level of compliance in the company is ideal ($\alpha = 1$), its size can be as big as we would like it to be, is correct from a mathematical point to view. However, this conclusion contradicts the popular principle of the economic theory, namely the Law on substantial growth of marginal and average

production costs, starting from a certain level of production output[13]. The reasons for this conclusion are hidden in the model (5) of production level accepted by the author. Later on, we will abandon this model and will develop models of the firm's optimal size. To do so we will take into account Commentary 1 and will use model (4) of costs paid for human labour and approximation (3)′ for the amount of human labour in the firm.

3. Optimal firm size models and the economic effect of collaborative interaction

In the specification of the discussed model of the firm's optimal size, we will keep the variables $(s, w_0, \beta, w_i; n, N, C_L)$ from O. Williamson's model. We will also preserve the relationships (2), (3)′ and (4)′ between these variables. When we model the firm's revenue R for the certain period, we will assume that variable R is determined by the levels of the production factors (resources) $(x_1, x_2, \dots, x_m)$ and the used technology F[14] in the company. In other words, we will view R as a representation of the firm's production function:

$$R = F(x_1, x_2, \dots, x_m). \quad (12)$$

We will designate the prices of the production factors (the structural coefficients of the structural cost factors[15]) with the symbols $r_1, r_2, \dots, r_m$. Then the firm's costs C for obtaining revenues R can be determined (*provided that all other variables remain constant*) with the equation

[13] See **Intriligator,** M. Matematicheskie metodi optimizatsii i ekonomicheskaya teoriya. - M.: AIRIS PRESS, 2002, s.218.

[14] See **Klainer,** G. B. Proizvodstvenaya funktsiya: teoriya, metodi and primenenie – M.: Finanasi i statistika, 1986, s. 17.

[15] See **Klainer,** G. B. Proizvodstvenaya funktsiya: teoriya, metodi and primenenie – M.: Finanasi i statistika, 1986, s. 179.

$C = r_1 \cdot x_1 + \cdots + r_m \cdot x_m$. With reference to this, for the firm's profit (net revenues) NR we can use the formula

$$NR = R - C = F(x_1, x_2, \ldots, x_m) - (r \cdot x_1 + \cdots + r_m \cdot x_m). \quad (13)$$

The main and necessary production factors are the firm's core capital and human labour. For their levels, we will use traditionally the symbols *K* and *L* respectively, while for the production function (12) we will apply the Cobb – Douglas function for these factors, which will correspond to the "highest level of aggregating the resource indicators"[16]:

$$R = F(K, L) = A \cdot K^{\gamma} \cdot L^{\delta}. \quad (12)'$$

To determine the level of human labour L in equation (12)′ we use approximation (3)′ so that equation (13) for the net revenue (based on (12)′ and (4)′) is represented in the following manner (provided that all other variables remain constant):

$$NR = A \cdot K^{\gamma} \cdot L^{\delta} - r \cdot K + C_L) = A \cdot K^{\gamma} \cdot (s^{n-1})^{\delta} - (r \cdot K + w_0 \cdot s^n/(s - \beta)), \quad 13)'$$

where r is the price (the structural coefficient of costs) of the firm's core capital. When there is information and a methodology for assessing the parameters of function (12)′, the coefficients γ и δ can be viewed as the meaning of elasticity of the firm's revenues with reference to the production factors *K* and *L*. Therefore, based on the assumption that the output function (12)′ in the economic area (the area of its determination M) complies with Gossen's Law of diminishing the marginal utilities of production factors, we can formulate the following inequality for the values of the mentioned coefficients:

$$0 < \gamma < 1, \ 0 < \delta < 1. \quad (14)$$

Let us now discuss equation (13)′ of the firm's net revenue. The level of the core capital in this equation can be both an exogenous and endogenous variable. For a short – term period it is natural to view this variable as *exogenous.* In this case, the necessary condition for an optimal number of hierarchical levels n^* in the company coincides with (9) but this

[16] **Klainer,** G. B. Proizvodstvenaya funktsiya: teoriya, metodi and primenenie – M.: Finanasi i statistika, 1986, s. 20.

time n^* is calculated with the help of a different formula:

$$n^* = 1 + \frac{1}{(1-\delta)\cdot \ln s} \cdot \left[\gamma \cdot \ln \mathrm{K} + \ln A \cdot \delta - \ln w_0 - \ln \frac{s}{s-\beta}\right]. \quad (15)$$

The result of the substitution of n^* in the right equation (3)′ is the model of the optimal size of a firm *in the short run*:

$$lnN^* = \frac{1}{(1-\delta)} \cdot (\gamma \cdot \ln \mathrm{K} + \ln A \cdot \delta - \ln w_0 - \ln \frac{s}{s-\beta}). \quad (16)$$

The analysis of the model (16) allows us to make following conclusions:

1. The optimal firm size N^* depends on the level of its core capital K and an increase in this level (provided that the other variables remain constant) leads to an increase in the optimal size of the company.

2. An increase in the elasticity γ of wages according to the level of core capital leads to an increase in the optimal firm size.

3. An increase in the elasticity δ of wages according to the level of human labour (because of collaborative interaction) and an improvement of the firm's production function (an increase in the coefficient of the collaborative productivity of factors A) results in an increase in the optimal firm size.

4. An increase in the wage w_0 of staff from the lower hierarchical levels and an increase in the multiplier β of wages of staff between the hierarchical levels results in diminishing the optimal firm size.

5. An increase in the span of control s results in increasing the optimal firm size.

In model (16) the level of core capital K of the firm is an exogenous variable (its value is determined). Therefore, the optimal firm size, determined with the help of model (16) does not depend on the level of costs $C_K = r \cdot K$ for core capital. *For a long – term period*, it is appropriate to view the level of core capital K as an endogenous variable

(subject to clarification). Then, the optimal firm size N^*, and the optimal level K^* of its core capital can be determined based on (13) ´ with the help of the following optimization model:

$$\frac{\partial NR}{\partial n} = 0, \quad \frac{\partial NR}{\partial K} = 0. \tag{17}$$

It can be checked that with the additional requirement[17]

$$\gamma + \delta < 1, \tag{18}$$

to the production function (12)´ of the company, conditions (17) lead to the following formula for calculating the optimal number of levels in the tree hierarchy of the company:

$$n^* = 1 + \frac{1}{(1-(\gamma+\delta))\cdot \ln s} \cdot \left[(1-\gamma)\cdot(\ln\frac{\delta}{\gamma} - \ln w_0 - \ln\frac{s}{s-\beta}) + \ln(\gamma \cdot A) - \gamma \cdot \ln r\right] \tag{19}$$

If we substitute n^* in the right equation (3)´, we will obtain the desired model of the optimal firm size for a long – term period:

$$lnN^* = \frac{1}{(1-(\gamma+\delta))\cdot \ln s} \cdot \left[(1-\gamma)\cdot(\ln\frac{\delta}{\gamma} - \ln w_0 - \ln\frac{s}{s-\beta}) + \ln(\gamma \cdot A/r^{\gamma})\right]. \tag{20}$$

In turn, the optimal level of the firm's core capital can be calculated with the following model:

$$lnK^* = \frac{1}{1-(\gamma+\delta)} \cdot \ln(\gamma \cdot A) - \left(1 + \frac{\gamma}{1-(\gamma+\delta)}\right) \cdot \ln r + \left(1 - \frac{(1-\gamma)}{1-(\gamma+\delta)}\right) \cdot \left\{\ln w_0 + \ln\frac{s}{s-\beta} - \ln\frac{\delta}{\gamma}\right\}. \tag{21}$$

The analysis of models (20) – (21) allows us to make the following conclusions, which are completely consistent with neoclassical economic theory:

1. The optimal size of the firm N^* is final for both short – term and long – term periods.

2. An increase in elasticity δ of revenues according to the level of human labour (for example, because of collaborative interaction) and an improvement of the firm's production function (an increase in the coefficient of the collaborative productivity of factors A) can lead to an increase in the optimal firm size.

[17] See **Klainer,** G. B. Proizvodstvenaya funktsiya: teoriya, metodi and primenenie – M.: Finanasi i statistika, 1986, s. 202.

3. Reduction of the price r of the firm's core capital (because of collaborative interaction, for example) is equal to an increase in both the optimal firm size and the optimal level of its core capital.

4. An increase of wages w_0 of employees on the lower hierarchical levels and an increase in the multiplier β of wages of staff between the hierarchical levels can lead to diminishing the optimal firm size and the optimal level of its core capital.

5. An increase in the span of control s leads to an increase in the optimal firm size but also results in diminishing the optimal level of its core capital.

Conclusion

When a company applies the principle of collaborative interaction and works with *partners who use their own core capital* (premises, computers, etc.), it reduces the average cost r of its own core capital and therefore its production costs. This fact in particular is the main reason for the successful implementation of collaborative interaction with reference to cost effectiveness.

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D. A. Tsenov Academy
of Economics, Svishtov

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