Е к о н о м і к а   п і д п р и є м с т в

S. O. Ishchuk

Simulating the duration of the operating cycle of industrial enterprises

Theoretical aspects of research of cyclic recurrence of economic processes have been shown. The method for determining the duration of the cycle of simple reproduction, i.e. production and sales (or operating) cycle, has been proposed, which allows to estimate the rate of transformation of current assets of industrial enterprises, and carry out variant calculations of production increase rate by changing the structure of current operating costs. The mathematical model of operating cycle calculation has been elaborated and approved at the level of industrial enterprises. The organizational and economic methods of operating cycle duration shortening at the level of region have been substantiated.
Keywords: operating cycle, industrial enterprise, production capacity, current operating costs.

A periodicity of the vast majority of processes (not only economic and technological, but also social) that occur in the economic system, is an integral part and at the same time the characteristic feature of competitive relations in the society. The market conditions as a barometer of the economy are determined by the expansion or shrinkage of the business activity. The monitoring of the business activity allows to select time intervals during which production of goods and services increases, then reduces and declines further, and then increases once more. These time intervals form the global economy development cycles, which are also called business cycles.

The formation of competitive management principles in Ukraine and further European integration encourages local researchers for advanced study of economic cycles. In economics the Keynesian and neoclassical theories of business cycles (or cycles of inventory investments) (Harrod R. F., Hicks J. R., Hansen A. H., Friedman M., Schwartz A. J., Lucas R. E.), the research of which were conducted largely from macro-level positions are well-known [1-5]. However, much less attention was paid to the cyclical economic processes at the micro level, although these processes are very important because the value added is creating at the individual business level, and thus the national income is forming.

The goal of article is to develop a model of determination the duration of simple reproduction cycle, i.e. production and sales (or operating) cycle, which allows to estimate the rate of transformation of current assets of industrial enterprises, and carry out variant calculations of production increase rate by changing the structure of current operating costs.

Between the times of using resources and obtaining financial results from industrial activity there is a certain interval. This interval is the implementation of economic transaction cycle, or period of simple reproduction. In contrast to the long investment cycles related with expanded reproduction of productive capacity, implementation of the economic transaction cycle belongs to the short-term ones.

The period of simple reproduction of the industrial enterprise covers two cycles: production and circulation. Within the first cycle the transformation of productive resources into the final products, and within the second cycle - the movement of final products (in time and space) from manufacturer to consumer, occurs. The longer is each of these cycles, the more working capital is in the forms of work in progress, stock, final products in warehouses and en route. Each phase of the implementation of economic transaction cycle, which can also be called as operating (or "production-sale") cycle and often treated as a period between the purchase of raw material resources for production activities, and obtaining funds from the sale of products made from these resources, is important for industrial enterprises.

© S. O. Ishchuk, 2016.

To determine the mathematical dependence between output growth index and duration of the operating cycle, we accept that all profit received is directed to the maintenance and expansion of existing production by replenishing working capital and wage fund.

Net profit of the enterprise P_{t+t} at time $t+t$ is:

$$P_{t+t} = (1 - \alpha)[(1 - \beta)(X_{t+t} - Y_t) - (1 + \gamma)F_t], \qquad (1)$$

where t – time of the cycle beginning;
      t – duration of the cycle of production and sales (in months);
      X_{t+t} – cost of sales at the time $t+t$;
      Y_t – cost of raw materials used at the time t;
      F_t – wage fund, used for the cycle;
      α – income tax (in fractions of a unit);
      β – value added tax (in fractions of a unit);
      γ – payroll charge (in fractions of a unit).

Wage fund is a cumulative value, which can be calculated as follows:

$$F_t = \sum_{i=1}^{\tau} w_{t+i} L_{t+i}, \qquad (2)$$

where w_{t+i} – wage per one employee in the i-th month;
      L_{t+i} – production staff in the i-th month.

Obtaining a profit P_{t+t} the enterprise repeats the production cycle in time $t+t$, replenishing and expanding working capital and wage fund, according to the currently prevailing structure of financial expenditures, i.e.

$$Y_{t+t} = Y_t + P_{t+t} i_{t+t}, \qquad (3)$$

$$F_{t+t} = F_t + P_{t+t}(1 - i_{t+t}), \qquad (4)$$

where i_{t+t} – the coefficient of profit distribution between material costs and expenditures for the maintenance of production stuff at the time $t+t$.

The average growth indices are:
– of the average wage per employee

$$J_w = w_{t+1} / w_t; \qquad (5)$$

– of the number of production staff

$$J_N = L_{t+1} / L_t; \qquad (6)$$

– of the amount of working capital

$$J_Y = Y_{t+1} / Y_t;$$

(7)

– of the enterprise output

$$J_X = X_{t+1} / X_t;$$

(8)

– of the material efficiency (reciprocal value to the material capacity) – J_R;
– of the labor productivity – J_L.

We accept that all the indices are the same for any t, that are assumed stable over time. Then

$$J_Y^\tau = (J_X / J_R)^\tau,$$

(9)

what allows us to record the left side of (3) as follows:

$$Y_{t+\tau} = Y_t (J_X / J_R)^\tau.$$

(10)

Based on the growth indices of production and labor productivity, we find the index of the number of production staff:

$$J_N = J_X / J_L.$$

(11)

In view of (11) the wage fund can be calculated as follows:

$$F_t = w_t L_t \sum_{i=1}^{\tau} (J_w J_X / J_L)^i,$$

(12)

$$F_{t+\tau} = w_{t+\tau} L_{t+\tau} \sum_{i=1}^{\tau} (J_w J_X / J_L)^i =$$
$$= w_t L_t (J_w J_X / J_L)^\tau \sum_{i=1}^{\tau} (J_w J_X / J_L)^i$$

(13)

Considering (3), (4), (10), (12) and (13), we obtain:

$$P_{t+\tau} = Y_t \left[(J_X / J_R)^\tau - 1 \right] +$$
$$+ w_t L_t \sum_{i=1}^{\tau} (J_w J_X / J_L)^i \left[(J_w J_X / J_L)^\tau - 1 \right]$$

(14)

We introduce in the analysis the structural indicators that will considerably simplify further calculations:

– the part of labor costs in revenue from sales (wage capacity):

$$y = w_t L_t / X_t ; \qquad (15)$$

– the proportion of raw material costs in the revenue from sales (material capacity in value terms):

$$r = Y_t / X_t . \qquad (16)$$

Inserting (14) into (1) and taking into account (15) and (16), we obtain the following equation:

$$(1-\alpha)(1-\beta)J_X^\tau - \rho\left[(1-\alpha)(1-\beta) + (J_X/J_R)^\tau - 1\right] -$$
$$-\psi \sum_{i=1}^{\tau}(J_w J_X/J_L)^i\left[(1-\alpha)(1+\gamma) + (J_w J_X/J_L)^\tau - 1\right] = 0. \qquad (17)$$

Formula (17) shows the mathematical dependence between the rate of increase in output and the level of current enterprise expenditures. Herewith an operating cycle duration t, which is related with all other variables by non-linear way, plays an active role in shaping the economic policy of production development. Accordingly, equation (17) is the methodological tool for assessing the required rate of capital turnover (in the sense of current assets). Having the necessary input raw data and applying numerical methods for solving equations, we can calculate the maximum allowable level of operating cycle[1] of the enterprise, which allows it to enter the path of economic growth (determined by index J_X).

The calculation results of t, performed for enterprise X, showed that theoretical duration of production and sale cycle for batch of products (wooden doors) is 13.5 days and almost matches the actual duration of the operation cycle of these products (~14 days), and this proves the adequacy of the model elaborated.
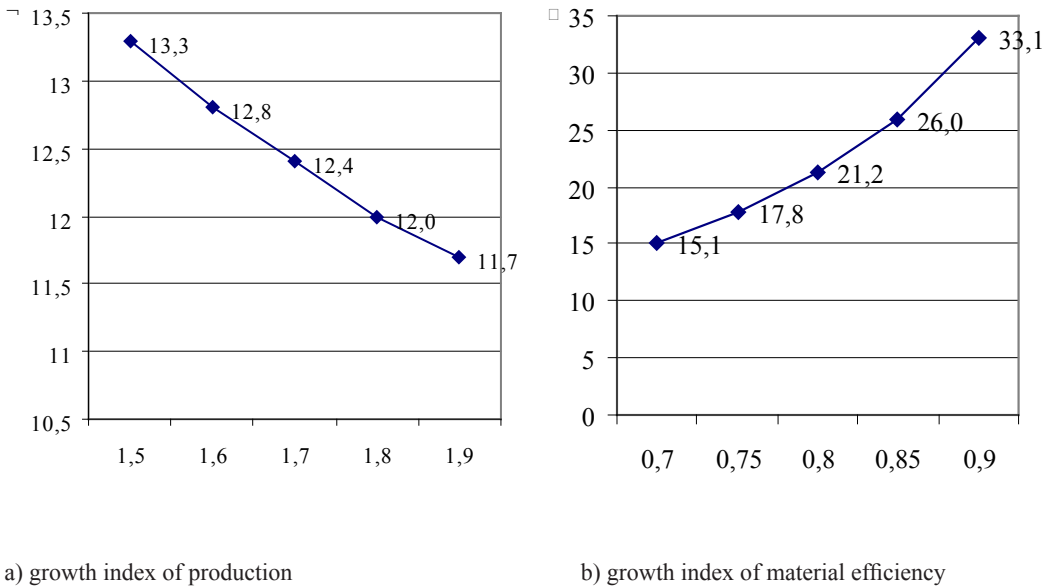
The study of dependences between t and growth indices of production and material efficiency performed on the example of enterprise X, revealed trends of operating cycle reduction with increasing (while baseline $J_R = 0,66$) (Fig. 1a) and vice versa – of cycle elongation with increasing J_R (while baselines $J_X = 1,46$) (Fig. 1b). This can be explained by the increase in labor-output ratio which in its turn lengthens the production cycle because less consumption of materials requires prolonged processing.

The simultaneous increase of growth indices of production and material efficiency (Table 1) continues operating cycle, but its duration is relatively less than with the increase only J_R, and it proves the efficiency of production scale growth.

There are other areas for application of the model (17). For example, having the necessary information (excepting index J_X) we can perform forecast calculations to determine the maximum production growth rate for a given value and structure of productive capacity and with existing technical and technological features of production processes at the enterprise.

More complex schemes for using (17) may be related with variant calculations for evaluation the cost structure and the tax burden, and these could allow to achieve the planned increase in

---

[1] The maximum permissible level is considered as an operating cycle duration, exceeding which will not allow to provide the required production output in due time.

a) growth index of production

b) growth index of material efficiency

**Fig. 1. Dependences between *t* and growth indices
of production and material efficiency**

production volumes at the sectoral, regional or national levels. Herewith it is necessary to calculate simultaneously the concurrent economic indicators, such as:

– for the cost structure – wage and material capacity of production;

– for the tax burden – taxes on income and value added, and charge on personal income.

This scheme of using the model (17), in contrast to its main purpose – to determine the duration of enterprise operating cycle – requires, on the one hand, a series of simulation experiments, and on the other – the optimization calculations. The latter can help to determine the optimal tax rate for the current economic conditions in the country, followed by assessment of the maximum production growth rate.

Both economic and institutional factors affect the duration of the operational cycle. In particular, wrong calculation of the required amount of commodity and material stocks can lead to failure of the production program or to the growth of operating costs. The ways of improving the management of commodity and material stocks as an important component of almost all business transactions lie in reduction of total costs associated with the delivery and storage, as well as in determining their optimal amount. These methods allow assuring the rhythm for the manufacturing and sales processes, what simultaneously guarantee stable operating cycle duration in the industry.

With a help of a flexible price policy the operating cycles can be reduced. Thus, the efforts to reduce enterprise sale cycle usually require its willingness to achieve compromises on sale conditions, because in practice the shortening of the cycle becomes possible under the condition of price reduction for the product, i.e. when changing producer price strategy. The situation is similar in the case of introduction of innovations in manufacturing processes, as they (innovations) increase the overall technical and technological level of production and consequently lead to costs reduction, thus creating preconditions for reducing prices for industrial products.

There is certain reserve for reducing the operating cycle duration and therefore the acceleration of economic development of the domestic industry in the organization of production. The overall

Table 1

Dynamics of duration of the operating cycle of the enterprise *X*
while the growth indices of production and material efficiency change

Index change type	Indicators		
	Production growth index J_X	Material efficiency growth index J_R	Operating cycle duration in days τ
Growth of J_X	1,50	0,66	13,3
	1,60	0,66	12,8
	1,70	0,66	12,4
	1,80	0,66	12,0
	1,90	0,66	11,7
Growth of J_R	1,46	0,70	15,1
	1,46	0,75	17,8
	1,46	0,80	21,2
	1,46	0,85	26,0
	1,46	0,90	33,1
Simultaneous growth of J_X and J_R	1,50	0,70	14,9
	1,60	0,75	16,6
	1,70	0,80	18,8
	1,80	0,85	21,4
	1,90	0,90	25,0

production cycle of large industrial facilities (territorial and production systems), which include several units connected by a rigid technological chain, is formed by smaller separate cycles. It is obvious that the more stages the raw material resources pass in the process of their transformation into the final product, the longer the duration of the operating cycle of production system is. That is why to speed up the turnover of current assets and to reduce operating cycle, under certain circumstances it is reasonable to divide basic company into several formally independent companies or units, technologically connected with each other, and afterwards unified (for example, in form of a concern). Thus, the reorganization of territorial production system determines the appropriate implementation of cost accounting, because a review of all costs is taking place at the beginning of each subsequent stage of the process, taking into account internal (or transfer) prices (i.e. prices, on the base of which agreements between individual enterprises are concluded). Respectively the strategy of transfer prices, chosen by the management of such industrial union, is the main factor in view of which the expediency of separation of technological units is determined.

The duration of the operating cycle generally depends on the temporal and dimensional isolation between separate elements of territorial production system, and between their formation processes and the processes of product sales, as well as on the level of development of market infrastructure in the region, what in turn helps to overcome an isolation caused by the deepening of labour division. Thus, the expansion of market infrastructure of the regions, as well as its organizational and technical improvements, stabilize (and sometimes reduce) the time of circulation of enterprise working capital, and this happens through connecting the separate and remote from

each other elements of the territorial production system, which in turn positively affects the duration of the operating cycles.

References

1. Harrod, R. F. (1936). *The Trade Cycle*. Oxford: Clarendon Press.
2. Hicks, J. R. (1950). *A Contribution to the Theory of the Trade Cycle*. Oxford: Clarendon Press.
3. Hansen, A. H. (1964). *Business Cycles and National Income*. London: Allen and Unwin.
4. Friedman, M., & Schwartz, A. J. (1963, February). Money and Business Cycles. *Review of Economics & Statistics*, 45, 32-64.
5. Lucas, R. E. (1977). Understanding business cycles. *Carnegie-Rochester Conference: Series on Public Policy*. Vol. 5.

Іщук С. О. Моделювання тривалості операційного циклу промислових підприємств

Становлення в Україні повноцінних ринкових засад управління національним господарством і подальша євроінтеграція спонукають до поглибленого вивчення економічних циклів, зокрема на мікрорівні, оскільки саме на рівні окремих підприємств створюється додана вартість, а відтак формується національний дохід суспільства загалом.

Метою статті є розробка моделі визначення тривалості циклу простого відтворення, тобто виробничо-реалізаційного (або операційного) циклу, який дозволяє оцінювати швидкість трансформації оборотних активів промислових підприємств і здійснювати варіантні розрахунки темпів нарощування виробництва шляхом зміни структури поточних витрат.

Дослідження залежностей між тривалістю операційного циклу й індексами росту виробництва та матеріаловіддачі, проведені на прикладі деревообробного підприємства, виявили тенденції скорочення операційного циклу при зростанні обсягів виробництва і навпаки – подовження циклу при зростанні матеріаловіддачі. Останнє пояснюється збільшенням трудомісткості виготовлення продукції, що, своєю чергою, подовжує виробничий цикл, оскільки менша витрата матеріалів вимагає тривалішої обробки. Одночасне збільшення індексів росту виробництва і матеріаловіддачі продовжує операційний цикл, однак його тривалість є порівняно меншою, аніж при збільшенні лише матеріаловіддачі, а це доводить ефективність зростання масштабу виробництва.

За допомогою розробленої моделі можна здійснювати прогнозні розрахунки для визначення максимальних темпів зростання виробництва при заданих обсягах та структурі виробничого потенціалу і техніко-технологічних особливостях виробничих процесів на підприємстві. Складніші схеми застосування цієї моделі можуть бути пов'язані з варіантними розрахунками в процесі оцінки структури витрат і рівня податкового навантаження, які дозволять забезпечити досягнення запланованих обсягів зростання виробництва на галузевому, регіональному чи загальнодержавному рівнях. При цьому необхідно розраховувати одночасно кілька економічних показників, а саме: для структури витрат – зарплатомісткість і матеріаломісткість продукції; для податкового навантаження – ставки податків на прибуток і на додану вартість і величину нарахувань на доходи фізичних осіб. Така схема застосування моделі, на відміну від основного призначення – визначення тривалості операційного циклу підприємства – передбачає, з одного боку, проведення серії імітаційних експериментів, а з другого, – виконання оптимізаційних розрахунків. За допомогою останніх можна визначити оптимальні податкові ставки для наявних економічних умов господарювання в країні з подальшою оцінкою максимального темпу зростання виробництва.

Ключові слова: виробничо-реалізаційний (операційний) цикл, промислове підприємство, обсяги виробництва, поточні витрати.

Іщук Світлана Олексіївна – доктор економічних наук, професор, завідувач відділу розвитку виробничої сфери регіону та інвестицій ДУ «Інститут регіональних досліджень імені М. І. Долішнього НАН України» (e-mail: iso.ird@ukr.net). Ishchuk Svitlana Oleksiyivna – Dr. Sci. (Econ.), Prof., Head of the Department of development of industrial sphere of the region and investment of the SI "Institute of Regional Research n.a. M. I. Dolishniy of the NAS of Ukraine".