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Simulative Analysis of a Company on the Basis of a Dynamic Econometric Model

1. An Econometric Model Describing the Construction Company

The study is aimed at the simulative analysis of decision-making process in the construction company. The studied company provides constructions as a general constructor and is active as a subcontractor. It specializes in reinforced concrete constructions. For two years there have been five branch offices in Poland and three abroad. Before, the company had three branch offices: two at home and one abroad. An increase of production in the company has last been observed.

The monthly data from January 2001 to December 2004 was the basis for this study. An eight-equation econometric model was developed according to the congruent modeling procedure for this company. The specification procedure consisted of 2 stages: the analysis of the internal structure of studied processes and analysis of causal relationships. Two models were estimated: a linear and a multiplicative ones. Both models had affinity concerning significance of parameters, direction and their magnitude. However, the multiplicative model describes some essential, observed elements of affiliation in the company worse, therefore only the linear one is presented here.

The creation of a modular-relational structure[1] of the studied company, which shows resources and information feedbacks, is the starting point of the model building. The background for this analysis is a module-relation attitude based on the system dynamics and the value chain. Such a structure creates a framework for the specification of the model's equations. An affiliation of characteristic variables describing the particular modules is presented at

[1] See: Stryjewski (2003), Stryjewski (2005).

fig. 1. Thereafter, the results of estimation for essential structural parameters of the congruent model are presented.

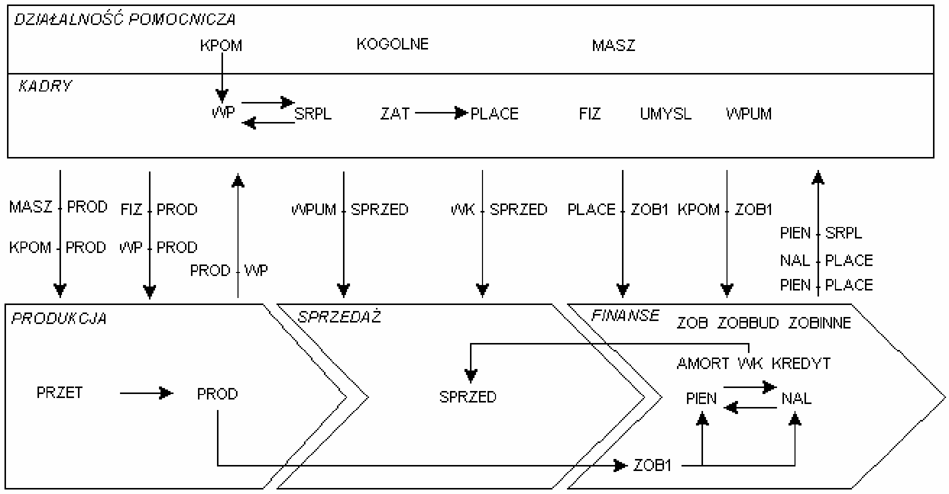

Fig. 1. Modular-relational structure of the construction enterprise
Source: Author's elaboration.

The estimated equations are given as follows.

$$NAL = -\underset{\pm143222,6}{286105.21} + \underset{\pm0,045}{0.975}\,NAL_{-1} + \underset{\pm0,069}{0.9507}\,SPRZED - \underset{\pm0,085}{0.9661}\,PIEN + \underset{\pm0,0706}{0.1516}\,PIEN_{-1}$$
$$-\underset{\pm428247,5}{1361253.8}\,S1 + \underset{\pm261500,1}{246442.18}\,S2 + \underset{\pm257425,6}{368319.2}\,S3 + \underset{\pm218427,3}{354620.6}\,S4 + \underset{\pm230036,4}{367364.8}\,S5$$
$$+\underset{\pm228382,1}{260062.03}\,S6 - \underset{\pm247168,8}{639194.2}\,S7 - \underset{\pm257089,3}{149930.9}\,S8 + \underset{\pm214431,5}{247722.4}\,S9 + \underset{\pm213875,3}{184773.9}\,S10$$
$$+\underset{\pm223004,1}{135941.84}\,S11 + \varepsilon_{T1},\ R^2 = 0.99,\ DW = 2.43,$$

$$PROD = -\underset{\pm1381656}{13756643} + \underset{\pm137267,7}{1321370}\,T - \underset{\pm5275,85}{46841.53}\,T^2 + \underset{\pm65,89}{539.94}\,T^3 + \underset{\pm4,0171}{19.45}\,KPOM$$
$$+\underset{\pm2607,06}{24904.37}\,FIZ + \underset{\pm2,37}{15.23}\,WP + \underset{\pm244177,8}{652968.6}\,H2 + \underset{784424,5}{3330643}\,PRZET_{-1} + \varepsilon_{T2}$$
$$R^2 = 0.955,\ DW = 2.53,$$

$$SPRZED = -\underset{\pm129795,7}{116509} + \underset{\pm179,9}{362.73}\,T^2 + \underset{\pm0,104}{0.746}\,SPRZED_{-1} + \underset{\pm0,0624}{0.154}\,PROD$$
$$+\underset{\pm1,645}{31.486}\,WPUM - \underset{\pm3,3688}{24.84}\,WPUM_{-1} - \underset{\pm24,85}{56.82}\,WK + \varepsilon_{T3},\ R^2 = 0.989,\ DW = 2.075,$$

$$PIEN = \underset{\pm 150526,2}{-320182.7} + \underset{\pm 0,072}{0.18}\,PIEN_{-1} + \underset{\pm 0,095}{0.906}\,SPRZED - \underset{\pm 0,091}{0.921}\,NAL + \underset{\pm 0,087}{0.918}\,NAL_{-1}$$
$$- \underset{\pm 422717,9}{1511902}\,S1 + \underset{\pm 290278,4}{172542.4}\,S2 + \underset{\pm 288189,2}{290721.3}\,S3 + \underset{\pm 246816,8}{267370.9}\,S4 + \underset{\pm 258817,7}{290692.6}\,S5$$
$$+ \underset{\pm 244984}{310627.7}\,S6 - \underset{\pm 292704,5}{483440.8}\,S7 - \underset{\pm 273498,9}{278796.6}\,S8 + \underset{\pm 236551,8}{220021.6}\,S9 + \underset{\pm 236814,7}{131508.2}\,S10$$
$$+ \underset{\pm 240578,7}{199775.6}\,S11 + \varepsilon_{T4},\ R^2 = 0.988,\ DW = 2.61,$$

$$ZOB1 = \underset{\pm 700498,3}{439734.2} + \underset{\pm 43801,47}{211183}\,T - \underset{\pm 936,96}{5339.39}\,T^2 + \underset{\pm 0,098}{1.193}\,PROD + \underset{\pm 0,134}{0.271}\,PROD_{-1}$$
$$+ \underset{\pm 1,64}{4.353}\,PLACE_{-1} + \underset{\pm 4,463}{11.777}\,KPOM_{-1} + \varepsilon_{T5},\ R^2 = 0.94,\ DW = 1.897,$$

$$PLACE = \underset{\pm 7822,1}{28236.57} - \underset{\pm 3,958}{9.553}\,T^2 + \underset{\pm 0,0392}{0.853}\,PLACE_{-1} + \underset{\pm 83,81}{1718.56}\,ZAT$$
$$- \underset{\pm 83,16}{1583.51}\,ZAT_{-1} + \varepsilon_{T6},\ R^2 = 0.97,\ DW = 1.73,$$

$$SRPL = \underset{\pm 73,97}{241.39} + \underset{\pm 12,04}{53.48}\,T - \underset{\pm 0,003}{0.0139}\,T^3 + \underset{\pm ,0163}{0.278}\,SRPL_{-1} - \underset{\pm 60,81}{21.8}\,S1 + \underset{\pm 58,43}{90.42}\,S2$$
$$- \underset{\pm 58,97}{26.44}\,S3 + \underset{\pm 51,85}{141.39}\,S4 + \underset{\pm 56,05}{37.59}\,S5 - \underset{\pm 51,56}{6.79}\,S6 + \underset{\pm 50,25}{45.11}\,S7 - \underset{\pm 50,61}{23.603}\,S8 - \underset{\pm 50,39}{58.77}\,S9$$
$$- \underset{\pm 51,72}{10.21}\,S10 - \underset{\pm 50,87}{83.403}\,S11 + \varepsilon_{T7},\ R^2 = 0.96,\ DW = 2.012,$$

$$WP = \underset{\pm 16114,34}{18584.09} + \underset{\pm 12,51}{31.52}\,T^2 + \underset{\pm 0,104}{1.3896}\,WP_{-1} - \underset{\pm 0,11}{0.62}\,WP_{-2} + \underset{\pm 25,72}{63.77}\,SRPL$$
$$- \underset{\pm 25,62}{74.65}\,SRPL_{-1} + \underset{\pm 0,00284}{0.0121}\,PROD - \underset{\pm 0,0035}{0.019}\,PROD_{-1} + \varepsilon_{T8},\ R^2 = 0.93,\ DW = 2.24,$$

where: NAL – amounts due, PROD – production costs, SPRZED – sales, PIEN – sales income, ZOB1 – all liabilities, PLACE – salaries and wages, SRPL – average wages, WP – workers productivity, KPOM – cost of subsidiary activities, FIZ – workers, PRZET – won contract rate, WPUM – staff productivity, WK – general cost/staff, ZAT – employees, UMYSL – staff, MASZ – tangible assets except lands and buildings, ZOB – liabilities in accordance with suppliers, ZOBBUD – liabilities in accordance with budget of state, ZOBINNE – other liabilities, KREDYT – loans value, KOGOLNE – general costs, AMORT – amortization.

The presented econometric dynamic congruent model of the construction company is characterized by high adjustment to the data. All values of determination coefficient are above 0.9 (also for the adjusted R^2). Furthermore the first order of autocorrelation in residuals of particular equations does not occur. The residuals are stationary (by ADF test). This model is likely to be appropriate for further simulative analysis.

2. Application of the Company's Econometric Model for Simulation

Generally simulations are divided into two groups:

1. deterministic,
2. stochastic.

A deterministic simulation serves for rendering the motion of the studied system. If we state that the simulation means setting in motion, this is a perfect definition of deterministic simulation, because of being an analysis of obtained trajectory of endogenous system variables. This trajectory consists of simulation data and copies the system running after its setting in motion. This motion is individual, unique i.e. for the equal system property (structural parameters, functions) and the equal values of exogenous variables, the model will always imitate the same trajectory. The change of the trajectory is possible only after changing any characteristic of the model or decision variable. So the deterministic simulation checks the reaction of the system for the changes of decision instruments.

A stochastic simulation is related to random variables in a model. Random variables in the model are the source of uncertainty. Model variables as well as estimators of its parameters and the residual component are random variables in econometric models. A stochastic simulation studies properties of random variables. The simulation sets the model repeatedly in motion generating adequate disturbances.

The deterministic simulation imitating the system in time can be done in two ways: static and dynamic. This is related to the understanding of lagged endogenous variables of the model. To calculate the system motion trajectory we can treat the endogenous variables in two ways:

1. static - lagged endogenous variables in the next iteration period are real values of the endogenous variable in the lagged period,
2. dynamic - lagged endogenous variables for the iteration are fitted values of this variable in the lagged period.

Values of MAPE[2] for the deterministic static and dynamic simulation of the company's model are presented in table 1.

[2] See: Welfe (2003), Gajda (2001).

Table 1. Values of MAPE for the deterministic static and dynamic simulation of the company's model

Variable	NAL	PROD	SPRZED	PIEN	ZOB1	PLACE	SRPL	WP
MAPE Dynamic	13.70	34.85	18.22	86.82	13.09	8.32	4.88	199.35
MAPE Static	12.89	33.81	12.74	76.72	11.86	5.28	4.38	118.76

Source: Author's own calculations.

The results collected in table 1 show the advantage of static simulation over the dynamic one. This is a natural status resulting from the properties of both types of simulations. A properly made model should be aimed at the minimalisation of differences in adjustment between the dynamic and static simulation. The simulation is considered as a simplification of multiplier analysis. It enables to avoid most of the problems related to establishing them by analytic methods. It is possible to compute multipliers using simulation without the necessity of designation of the final form of the model. A multiplier can be written as a derivative of equations system towards exogenous variable:

$$m_{y,x,s} = \lim_{\Delta x_s \to 0} \frac{y^{z}_{it} - y_{it}}{\Delta x_k}$$

where: $m_{y,x,s}$ – a vector of endogenous variable multiplier towards exogenous variable after s periods, y_{zit} – a vector of endogenous variable obtained from the disturbance simulation, y_{it} – a vector of endogenous variable obtained from the basic simulation without the disturbance, Δx_t – the change of an exogenous variable. The results of the multiplier analysis for the surveyed construction company as a system reaction for a 10% increase of the won contracts rate in the 5th period are presented in fig. 2.

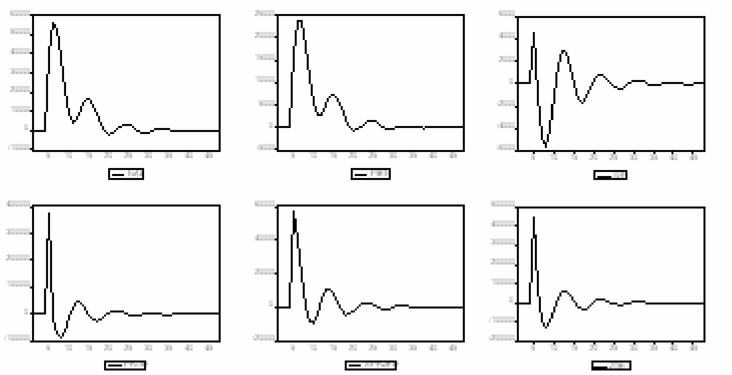

Fig. 2. Multipliers solution found by deterministic simulation
Source: Author's elaboration.

However, apart from the reasons detected and analyzed during the model building, endogenous and exogenous variables were formed under the influence of many constraints. An unconstrained simulation is possible in a retrospective analysis, because the data included in the sample has information about the constraints which is not available for the researcher. In order to simulate the formation of endogenous variables out of the sample, e.g. assuming various levels of the values of the variables, constraints regarding the real processes should be included in the simulation model.
The constraints can result from different circumstances, mostly from:
1. theory,
2. law regulations,
3. standards,
4. procedures,
5. surveyed subject policy and so on.

Including the constraints to the simulation model makes the obtained results real and enables to observe the system out of the sample. Furthermore, it makes possible to predict many variants of the system development in the changing environment.
The simulation including constraints gave more possibilities and caused an increase of the model flexibility as the decision analysis tool. Applying appropriate constraints is the reason for the increase of precision, concerning the mapping of real processes. The constraint of the variables nonnegativity (according to the economics theory) improves statistical performance of the model. The above fact is confirmed by the results presented in the table 2.

Table 2. The MAPE errors for constrained and non constrained simulation

MAPE								
Variable	NAL	PROD	SPRZED	PIEN	ZOB1	PLACE	SRPL	WP
Simulation without constraints	13.60	34.85	18.22	86.82	13.09	8.32	4.88	199.35
Simulation with constraints	17.89	31.83	10.96	63.67	11.68	8.32	4.80	143.49

Source: Author's own calculations.

Setting the model in motion for the predetermined initial values exemplifies using stochastic simulation in the management of company. Such stimulation is de facto an attempt at multi-step prediction. All exogenous variables for the sample period are calculated using univariate data generating models (trend – seasonal – autoregressive models) with disturbances depending on their residual processes characteristics. All variables in the survey are obtained by simulation. The experiment consisted of fifty observations and was repeated ten times. Each exogenous variable was calculated for each period separately.

As all variables were generated by simulation, additional constrains arising from the policy of studied company were imposed on endogenous variable.

An algorithm of stochastic dynamic simulation with disturbances is as follows:

1. Determination of starting conditions for the first four periods by sampling distribution.
2. Obtaining exogenous variables values on the ground of univariate data generating models with disturbances resulting from attributes of residual components.
3. For each t = i, where $i \in (1,50)$:
   a) Obtaining endogenous variables values on the ground of econometric model of the company with disturbances resulting from attributes of residual components.
   b) Imposing constraints on endogenous variables.

In the table 3 the results of the simulation are presented. In this table the values of MAPE error for deterministic dynamic simulation and mean value of MAPE error from all replications of stochastic simulation for the above algorithm are compared. Furthermore, endogenous variables plots for chosen replication are presented.

Table 3. The MAPE errors for non-constrained dynamic deterministic simulation and constrained stochastic simulation

	MAPE							
Variable	NAL	PROD	SPRZED	PIEN	ZOB1	PLACE	SRPL	WP
Dynamic deterministic simulation without constraints	13.60	34.85	18.22	86.82	13.09	8.32	4.88	199.35
Dynamic stochastic simulation with constraints	19.62	31.83	10.96	68.85	11.68	8.32	4.80	144.57

Source: Author’s own calculations.

Results presented in the table 3 meet the expectations. Generating all variables by unconstrained simulations causes worse adjustment to real data, while including the constraints improves the simulation model attributes. Therefore, MAPE errors for simulation with constraints is mostly smaller than for deterministic dynamic simulation without constraints. The data generated by stochastic simulation with constraints in accordance with the above-presented algorithm reveals matching the real data.

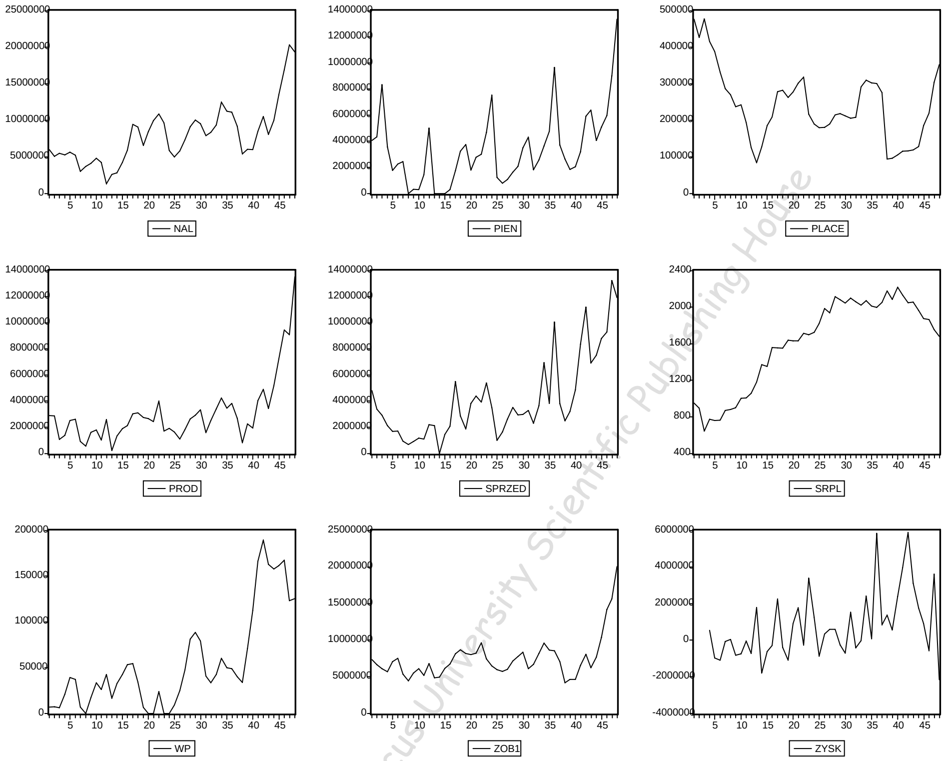

Figure 3. The endogenous variables trajectory in one of the replications of stochastic simulations

Source: Author's elaboration.

3. Conclusions

Simulation is a valuable cognitive element of the systems analysis. In the presented study, simulation was applied to the construction company analysis on the basis of the congruent econometric model. In the studied case the simulation turned out the simplest way of getting information resulting from the multiplier analysis. The essential element of system analysis is the knowledge of reproduction of its behavior by stochastic simulation of the econometric model. This kind of simulation enables modeling company's behavior in the future and analyzing effects of various decisions. So it is a valuable instrument for the company policy analysis.

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