CYBERNETIC VIEW OF MULTIPLIERS IN MACROECONOMIC THEORY

Pavel Rousek

Abstract

The aim of the paper is to extend the macroeconomic theory of multipliers by further potential relationships and to create a complex system of calculations that will better reflect reality.

Currently, three multipliers (expenditure, tax, and transfer multiplier) are calculated in three economies according to the market entities (two-sector, three-sector, and four-sector). So, there are nine basic multipliers. However, the feedbacks considered are very simplistic: the marginal propensity to consume as a positive relationship between product and consumption; the rate of the income tax as a negative relationship between product and consumption; the marginal propensity to import as a negative relationship between product and net exports.

The paper shows that there are much more potential feedbacks in macroeconomic models. The tool to reach the contribution goal is to find more macroeconomic feedbacks and add them into now multipliers that will be a more accurate reflection of reality. The added value of the author's work is to define new system feedbacks and implement them into new multipliers. Created cybernetic systems are a simplified abstraction of real macroeconomic relationships. The more complicated calculation will then be offset by more accurate results and closer reflection of reality.

Key words: Cybernetics, Systems Theory, Macroeconomics, Multipliers

JEL Code: C54, C67, E17

Introduction

The economy is a complex system with inputs, outputs, and links inside. At a macroeconomic level, for exogenous inputs are most often considered autonomous components of consumption, investments, government purchases, exports, and imports. The key output is then the amount of product. Internal economic links point forward or backward. Backward

links (or feedbacks) cause an infinitely repetitive reaction of the initial input. This principle is called a multiplication effect that can be measured as the sum of convergent infinite series.

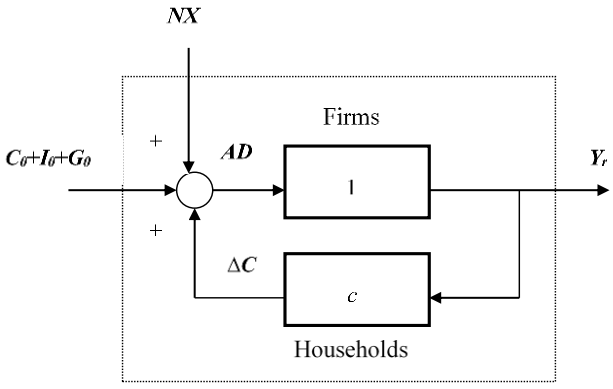
Traditional macroeconomic approach prefers three basic multipliers (expenditure, tax, and transfer) in three basic economic models (two-sector, three-sector, and four-sector economics). This paper shows that much more multipliers can be defined by the cybernetic approach and by the systems theory. This paper defines multipliers that are still neglected by macroeconomic theory. The two-phase process will lead to this goal: First, cybernetic models will be created. Second, new multipliers will be defined based on these models.

1 Traditional macroeconomic approach

Macroeconomic multiplication effect is described by Samuelson & Nordhouse (2000). "The multiplier is the impact of a 1-dollar change in exogenous expenditures on total output." This chapter is based on macroeconomic multipliers and transforms them into cybernetic models. The reason is to show the link between macroeconomic and cybernetic logic. The first attempts to implement cybernetic methods into macroeconomics have already been made by Lange (1970). He focused mainly on the basic Keynesian multiplier.

The basic cybernetic model includes the market for goods and services, where feedback is the dependence of consumption on the product (or income), which is expressed by the marginal propensity for consumption in Fig. 1.

Fig. 1: A cybernetic model of a static economy with the goods and services market



Source: Máče & Rousek (2013).

Cybernetics allows expression of the dependence of output change ΔY on exogenous input changes $\Delta(C_0+I_0+G_0+NX)$. Tatarkin et al. (2017) present "a method of estimating the

multiplicative effects, based on the balance sheet approach and the methodology of the system of national accounts." In any case, the output/input ratio is given by the multiplier (1).

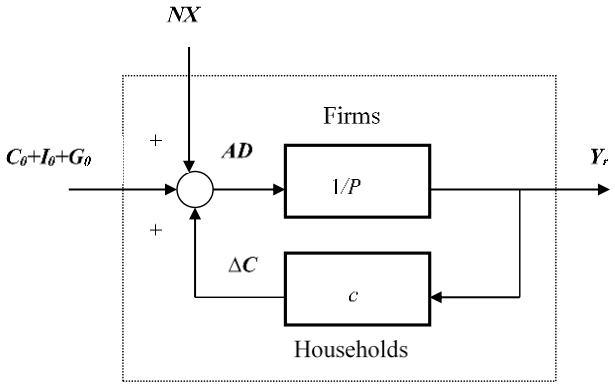
$$\Delta Y = \Delta(C_0 + I_0 + G_0 + NX) \times \frac{1}{1-c} \qquad (1)$$

Where Y is the product

C_0; I_0; G_0	autonomous consumption; autonomous investments; autonomous government purchases
NX	net export (NX = X – D = X_0 – mY + vR)
c	marginal propensity to consume, the sensitivity of consumption to product

The previous multiplier expression assumes a zero time-delay or a constant price level. Considering the inflation factor that occurs during the production process (in the firms' sector), the cybernetic model will look like what is shown in Fig. 2.

Fig. 2: A cybernetic model of a dynamic economy with the goods and services market



Source: Máče & Rousek (2013).

This change will then be reflected in the modified form of the multiplier (2).

$$\Delta Y = \Delta(C_0 + I_0 + G_0 + NX) \times \frac{\frac{1}{P}}{1-\frac{1}{P}c} = \Delta(C_0 + I_0 + G_0 + NX) \times \frac{1}{P-c} \qquad (2)$$

Where P is the change in the price level

Similarly, other two-sector, three-sector and four-sector economy multipliers can be deduced. Their overview is shown in Tab. 1.

Tab. 1: An overview of basic macroeconomic multiplies

	C_0, I_0, G_0, X_0	**T_0**	**Tr**
Two-sector economy	$\frac{1}{P-c}$	$\frac{c}{P-c}$	$\frac{-c}{P-c}$

Three-sector economy	$\frac{1}{P-c(1-t)}$	$\frac{c}{P-c(1-t)}$	$\frac{-c}{P-c(1-t)}$
Four-sector economy	$\frac{1}{P-c(1-t)+m}$	$\frac{c}{P-c(1-t)+m}$	$\frac{-c}{P-c(1-t)+m}$

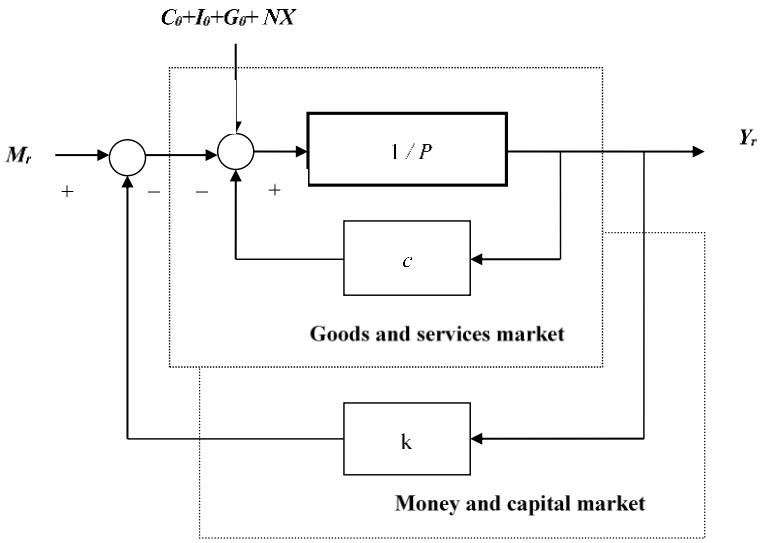
Source: Author

2 Innovative cybernetic approach

Cybernetics and systems theory describe the system with a model that includes exogenous inputs, endogenous forward links, endogenous feedbacks and outputs. Flows inside can be influenced by so-called regulators that are set (or influenced) by central. Depending on the complexity of the defined model, different macroeconomic multipliers can be defined.

The dynamic economy model with the goods and services market is now expanding with a simple representation of the money and capital market. Newly added exogenous input is the money supply. This is displayed in Fig. 3.

Fig. 3: A cybernetic model of a dynamic economy extended by the simple money and capital market



Source: Máče & Rousek (2013).

As can be seen in formula (3), any additional feedback appears in the denominator of the multiplier, and the change of the additional input is also multiplied. In this case, the additional input is the money supply. “The question of whether money supply in an economy is endogenously or exogenously determined is crucial for a proper formulation of macroeconomic theory and policy” Nayan et al. (2013). This paper assumes that at least some of the money supply is exogenous.

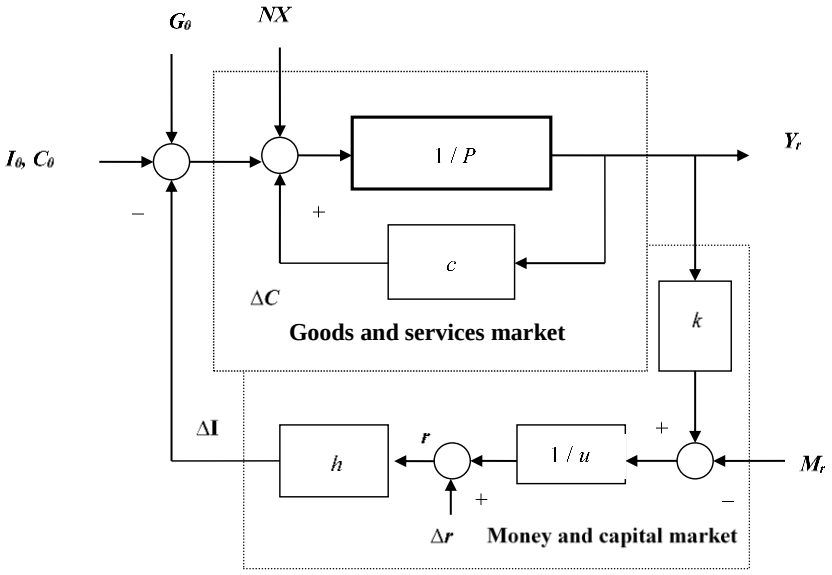
$$\Delta Y = \Delta(M_r + C_0 + I_0 + G_0 + NX) \times \frac{\frac{1}{P}}{1-\frac{1}{P}c-(-)\frac{1}{P}k} = \Delta(M_r + C_0 + I_0 + G_0 + NX) \times \frac{1}{P-c+k} \quad (3)$$

Where M_r is the money supply

k the sensitivity of money demand to real income

The above-mentioned money and capital market is too much simplification. There is introduced its more complex form in Fig. 4, which also considers the interest rate and other sensitivities to input parameters.

Fig. 4: A cybernetic model of a dynamic economy extended by the complex money and capital market



Source: Máče & Rousek (2013).

By adding more feedbacks, multipliers are expanding. At the same time, the different entry point of the system is manifested by different multiplication effects of autonomous expenditure (4), money supply (5), and interest rate (6). The theory of interest rate models is more fully described in Brigo & Mercurio (2001). Kalouda (2017) displays the banking sector as a cybernetic model, trying to derive the effects of negative interest rates.

$$\Delta Y = \Delta(C_0 + I_0 + G_0 + NX) \times \frac{\frac{1}{P}}{1-c\frac{1}{P}-(-)k\frac{h}{uP}} = \Delta(C_0 + I_0 + G_0 + NX) \times \frac{1}{P-c+k\frac{h}{u}} \quad (4)$$

$$\Delta Y = \Delta M_r \times \frac{\frac{h}{uP}}{1-c\frac{1}{P}-(-)k\frac{h}{uP}} = \Delta M_r \times \frac{\frac{h}{u}}{P-c+k\frac{h}{u}} \quad (5)$$

$$\Delta Y = \Delta r \times \frac{h\frac{1}{P}}{1-c\frac{1}{P}-(-)k\frac{h1}{uP}} = \Delta r \times \frac{h}{P-c+k\frac{h}{u}} \qquad (6)$$

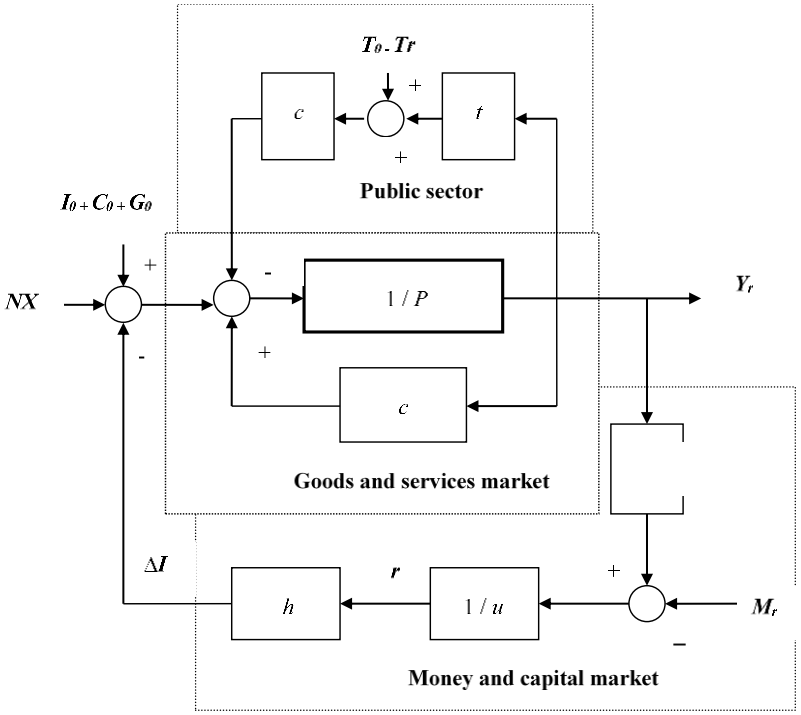
Where u is the sensitivity of money demand to a nominal interest rate

r domestic interest rate

h the sensitivity of private investments to real interest rate

Fig. 5 adds to the previous models the public sector that controls additional inputs into the system in the form of taxes and transfers.

Fig. 5: A cybernetic model of a dynamic economy extended by the public sector



Source: Máče & Rousek (2013).

Here, the inputs into the system are divided into four positions: autonomous expenditure (7), money supply (8), interest rate (9), and taxes and transfers (10). The importance of taxes and transfers and their effectiveness are assessed, for example, by Gechert (2015). General information about fiscal multipliers (what is it, what determines its size, which one should be used) gives Spilimbergo, Symansky, & Schindler (2009).

$$\Delta Y = \Delta(C_0 + I_0 + G_0 + NX) \times \frac{\frac{1}{P}}{1-c\frac{1}{P}-(-)tc\frac{1}{P}-(-)k\frac{h1}{uP}} = \Delta(C_0 + I_0 + G_0 + NX) \times \frac{1}{P-c(1-t)+k\frac{h}{u}} \qquad (7)$$

$$\Delta Y = \Delta M_r \times \frac{\frac{h1}{uP}}{1-c\frac{1}{P}-(-)tc\frac{1}{P}-(-)k\frac{h1}{uP}} = \Delta M_r \times \frac{\frac{h}{u}}{P-c(1-t)+k\frac{h}{u}} \qquad (8)$$

$$\Delta Y = \Delta r \times \frac{h\frac{1}{P}}{1-c\frac{1}{P}-(-)tc\frac{1}{P}-(-)k\frac{h1}{uP}} = \Delta r \times \frac{h}{P-c(1-t)+k\frac{h}{u}} \qquad (9)$$

$$\Delta Y = \Delta(T_0 - Tr) \times \frac{c\frac{1}{P}}{1-c\frac{1}{P}-(-)tc\frac{1}{P}-(-)k\frac{h1}{uP}} = \Delta(T_0 - Tr) \times \frac{c}{P-c(1-t)+k\frac{h}{u}} \qquad (10)$$

Where T_0 is an autonomous tax

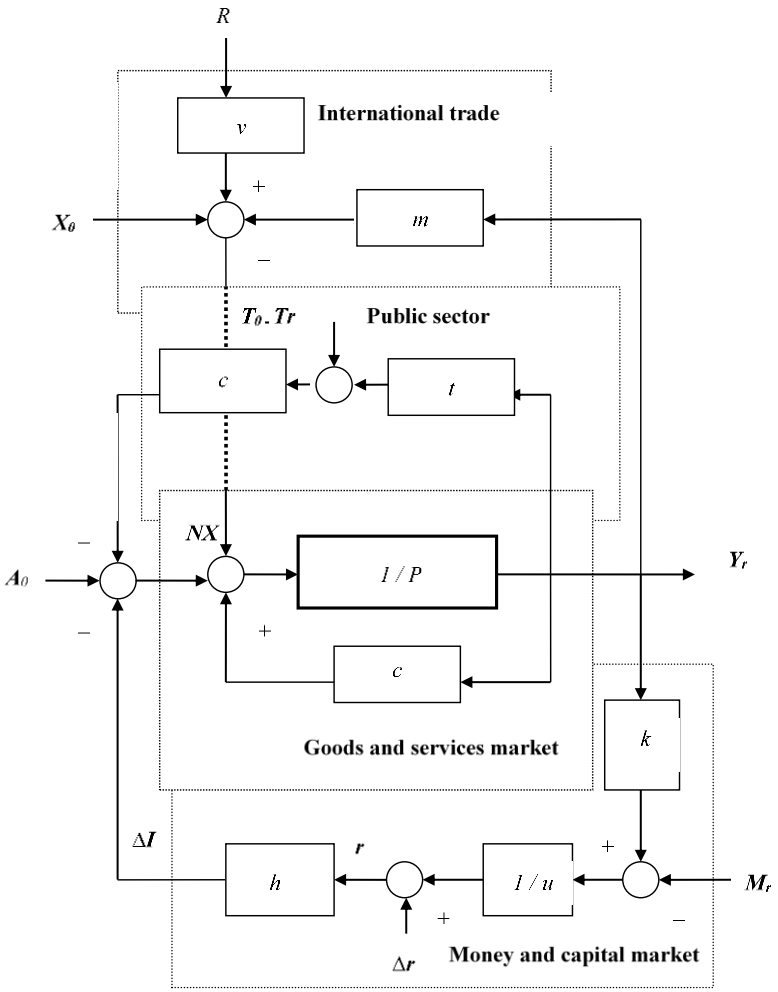
t rate of the income tax

T taxes ($T = T_0 + tY$)

Tr transfers

Finishing is the model of a dynamic economy with the goods and services market, the complex money and capital market, the public sector, and international trade (Fig. 6).

Fig. 6: A cybernetic model of a dynamic economy extended by the international trade



Source: Máče & Rousek (2013).

In addition to the original inputs (11, 12, 13, 14), we must also calculate the real exchange rate (15). In the modern economy, an increasingly important role is played by the cryptocurrencies, so it is also necessary to consider their exchange rate as evidenced by Osterrieder et al. (2017). However, the greatest attention must still be paid to the exchange rates of traditional currencies. Current factors such as Brexit's influence on the USD / GDP rate are important. Its importance show Clark & Amen (2017)

$$\Delta Y = \Delta(C_0 + I_0 + G_0 + X_0) \times \frac{\frac{1}{P}}{1 - c\frac{1}{P} - (-)tc\frac{1}{P} - (-)k\frac{h1}{uP} - (-)m} = \Delta(C_0 + I_0 + G_0 + X_0) \times \frac{1}{P - c(1-t) + k\frac{h}{u} + m} \quad (11)$$

$$\Delta Y = \Delta M_r \times \frac{\frac{h1}{uP}}{1 - c\frac{1}{P} - (-)tc\frac{1}{P} - (-)k\frac{h1}{uP} - (-)m} = \Delta M_r \times \frac{\frac{h}{u}}{P - c(1-t) + k\frac{h}{u} + m} \quad (12)$$

$$\Delta Y = \Delta r \times \frac{h\frac{1}{P}}{1 - c\frac{1}{P} - (-)tc\frac{1}{P} - (-)k\frac{h1}{uP} - (-)m} = \Delta r \times \frac{h}{P - c(1-t) + k\frac{h}{u} + m} \quad (13)$$

$$\Delta Y = \Delta(T_0 - Tr) \times \frac{c\frac{1}{P}}{1 - c\frac{1}{P} - (-)tc\frac{1}{P} - (-)k\frac{h1}{uP} - (-)m} = \Delta(T_0 - Tr) \times \frac{c}{P - c(1-t) + k\frac{h}{u} + m} \quad (14)$$

$$\Delta Y = \Delta R \times \frac{v\frac{1}{P}}{1 - c\frac{1}{P} - (-)tc\frac{1}{P} - (-)k\frac{h1}{uP} - (-)m} = \Delta R \times \frac{v}{P - c(1-t) + k\frac{h}{u} + m} \quad (15)$$

Where X_0 is an autonomous export

m	marginal propensity to import, the sensitivity of import to product
R	real exchange rate
v	the sensitivity of net exports to real exchange rate

In Tab. 2 there is an overview of 24 defined multipliers, which do not differ in the number of economic sectors considered but in the number and structure of the markets involved.

Tab. 2: An overview of the proposals for the extension of macroeconomic multipliers

	C_0, I_0, G_0, X_0	**M_r**	**r**
An economy model with the goods and services market	$\frac{1}{P - c}$	$\frac{h/u}{P - c}$	$\frac{h}{P - c}$
The previous model extended by the money and capital market	$\frac{1}{P - c + k\frac{h}{u}}$	$\frac{h/u}{P - c + k\frac{h}{u}}$	$\frac{h}{P - c + k\frac{h}{u}}$
The previous model extended by the public sector	$\frac{1}{P - c(1-t) + k\frac{h}{u}}$	$\frac{h/u}{P - c(1-t) + k\frac{h}{u}}$	$\frac{h}{P - c(1-t) + k\frac{h}{u}}$

The previous model extended by the international trade	$\frac{1}{P-c(1-t)+k\frac{h}{u}+m}$	$\frac{h/u}{P-c(1-t)+k\frac{h}{u}+m}$	$\frac{h}{P-c(1-t)+k\frac{h}{u}+m}$
	T_0	**Tr**	**R**
An economy model with the goods and services market	$\frac{c}{P-c}$	$\frac{-c}{P-c}$	$\frac{v}{P-c}$
The previous model extended by the money and capital market	$\frac{c}{P-c+k\frac{h}{u}}$	$\frac{-c}{P-c+k\frac{h}{u}}$	$\frac{v}{P-c+k\frac{h}{u}}$
The previous model extended by the public sector	$\frac{c}{P-c(1-t)+k\frac{h}{u}}$	$\frac{-c}{P-c(1-t)+k\frac{h}{u}}$	$\frac{v}{P-c(1-t)+k\frac{h}{u}}$
The previous model extended by international trade	$\frac{c}{P-c(1-t)+k\frac{h}{u}+m}$	$\frac{-c}{P-c(1-t)+k\frac{h}{u}+m}$	$\frac{v}{P-c(1-t)+k\frac{h}{u}+m}$

Source: Author

Conclusion

There could be defined links between autonomous and exogenous macroeconomic inputs (consumption, investments, government purchases, export, money supply, domestic interest rate, tax, transfers, exchange rate) and macroeconomic output (product). Forward and backward links ensure this correlation.

Traditional macroeconomic approach defines 9 basic multipliers that disregard some important feedbacks. The aim of the paper was to extend the macroeconomic theory of multipliers by further potential relationships and to create a complex system of calculations that will better reflect reality. This paper defines 24 different multipliers, but there is much more. The different complexity of cybernetic model ensures the creation of different multipliers.

The topic of further research is a critical evaluation of existing cybernetic models, possible modification of their parameters, creation a more comprehensive overview of potential multipliers, and especially quantification of sensitivities and marginal propensities in real economies. Knowledge of these parameters will make it possible to make more sophisticated estimates of the future development of the underlying macroeconomic indicator, i.e. GDP.

References

Brigo, D., & Mercurio, F. (2001). *Interest rate models: Theory and practice.* Berlin: Springer.

Clark, I., & Amen, S. (2017). Implied Distributions from GBPUSD Risk-Reversals and Implication for Brexit Scenarios. *Risks,* 5(3), 35. doi:10.3390/risks5030035

Gechert, S. (2015). What fiscal policy is most effective? A meta-regression analysis. *Oxford Economic Papers,* 67(3), 553-580. doi:10.1093/oep/gpv027

Kalouda, F. (2017). Negative interest rates - consequence staying in error? (empirical evidence). *14th International Scientific Conference on European Financial Systems 2017,* 290-299.

Lange, O. (1970). *Introduction to economic cybernetics.* Warszawa: PWN – Polish Scientific Publishers.

Máče, M., & Rousek, P. (2013). *Makroekonomie pro technické školy.* Praha: Grada.

Nayan, S., Kadir, N., Abdullah, M. S., & Ahmad, M. (2013). Post Keynesian Endogeneity of Money Supply: Panel Evidence. *Procedia Economics and Finance,* 7, 48-54. doi:10.1016/s2212-5671(13)00217-7.

Osterrieder, J., Chan, S., Chu, J., & Nadarajah, S. (2017). A Statistical Analysis of Cryptocurrencies. *SSRN Electronic Journal.* doi:10.2139/ssrn.2948315

Samuelson, P. A., & Nordhaus, W. D. (2010). *Economics.* New York: Tata McGraw-Hill.

Spilimbergo, A., Symansky, S., & Schindler, M. (2009). Fiscal Multipliers. Washington: International Monetary Fund.

Tatarkin, D., Sidorova, E., & Trynov, A. (2017). Simulation of Structural Changes in the Region's Economy Based on the Matrix of Financial Flows. *Economic and Social Changes: Facts, Trends, Forecast,* (1 (49)). doi:10.15838/esc.2017.1.49.12

Contact

Pavel Rousek

The Institute of Technology and Business in České Budějovice, School of Expertness and Valuation

Okružní 517/10, 370 01 České Budějovice, Czechia

rousek@mail.vstecb.cz