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Output and Energy Prices Fluctuations in Response to Market Shocks: System Dynamic Modeling

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ABSTRACT

Regardless of the fact, whether governments of particular country implemented the strong lockdown measures to prevent the spread of COVID-19 or not, the economies of each country all over the word have been suffered considerably due to the shocks caused by the pandemic. We observed slowdown of economic activity, macroeconomic instability and shifts in consumption preferences supplemented by rising unemployment as well as significant fluctuation of demand and production capability. The research problem addressed in this paper focuses on dynamic properties of output and inflation fluctuations that occur in response to economic shocks different magnitudes and types. We use a system dynamic approach and constructs two system dynamic models to examine the dynamics of output, prices, wage and inflation. The paper indicates ranges of relevant parameters' values that correspond with sensitivity of output to demand and production capability changes related to possibility of reaching new equilibrium point. To explore the variety of prices and wage behavior in response to shocks we evaluate distinguish possible phase diagrams associated with stable node, stable focus, circle, unstable focus and unstable node. The results is a contribution to discussion of the policy issues related to mitigation of recession caused by unpredictable and strong shocks.

Keywords: Output Fluctuation, System Dynamic Model, Energy Prices, Shock
JEL Classifications: O13, C 63, E37

1. INTRODUCTION

The last year the whole word has been suffered from the deep crisis caused by COVID-19 pandemic. The economy of every country has been hurt. Regardless of the fact, whether governments implemented the strong lockdown measures or not, economies of each country has been suffered considerably (Dorczak et al., 2021; Hryhoruk et al., 2021). The economic activity showed declining trend, macroeconomic instability has been observed (Skrypnyk and Nehrey, 2015; Guryanova et al., 2020) and, in result, the severe recession has occurred. The consumers were influenced not only by lack of doing their wonted traditional shopping but also by future uncertainty and general fear. Some part of demand turned into online shopping with flexible and very fluctuating prices. The output was restricted by many reasons that were brought about by lockdowns and border closures. International trade system and financial market incurred losses (Hayakawa and Mukunoki, 2021). The demand shocks as well as production shocks, that had been taking place almost simultaneously, disturbed the dynamics of output, wages and energy prices, had a huge asymmetric impact on dynamics unemployment and labor force participation (Lukianenko and Oliskevych, 2017), industrial enterprise (Matviychuk et al., 2019), wages, energy prices and socio-economic development of regions (Hryhoruk et al., 2020).

The severe and unpredictable disturbances are able to produce the nonlinear permanent effect (Maman and Maleki, 2022). The behavior of all economic indicators has undergone changes and their convergence to a new steady state (Oliskevych and Lukianenko, 2020) is a big question that is in interest of scientists as well as policymakers and public.

Shepherd (2018) focused on impact of negative shocks that provide transmission through an input-output network emphasizing the importance of network structure, international output-input linkages and interlinkages among the sectors of the economy and role of propagation. He discovered that the negative market shocks have significant impact on distant nodes that correspond to the eigenvector centrality scores of those nodes. Bazhenova et al. (2020) developed a wide range of contemporary nonlinear econometric models that take into account regime switching in unemployment rate and labor force to investigate the asymmetric nonlinear peculiarities in dynamics of European labor market indicators in response to shocks. Heimberger (2020) discusses the technical restriction of European Union fiscal rules and their impact on the fiscal space during of the COVID-19. They provided evidence for declining revision of EU output estimation and evaluated the potential consequences in term of fiscal policy. Scientists also emphasized that the estimation of direction and magnitudes for labor market factors responses on negative as well as on positive economic shocks are vitally important (Tokarchuk et al., 2018).

To investigate the behavior impact of economic variables in response to different shocks scientists often used econometrics vector autoregressive models as well as machine learning approaches (Babenko et al., 2021) that include supervised and unsupervised learning, fuzzy logic approach (Matviychuk, 2006) and predictive analytics (Guryanova et al., 2020). Oduyemi and Owoeye (2020) explored the fluctuation of oil prices and health outcomes in Nigeria. They showed that in oil exporting countries the dependence of government finance from oil revenue and its trend caused instability in income, fiscal balance, growth rate and human capital development. The researches combined evaluation of long-term relationships between energy sources and their short-term dynamics description. It was found two equilibrium relationships and adjustments forces that determined the fuel consumption dynamics in Ukraine (Oliskevych et al., 2019).

Hernández (2019) revealed the synchronization of fluctuation in Latin America and US. Based on panel data analysis he suggested the reasons of Latin American macroeconomic exposure to external shocks and emphasized the importance of geo-economic source of output fluctuations for the region. Kaminskyi et al. (2020) estimated the sensitivity to shocks in probability and based on measuring variability with applying the Value-at-Risk concept represented the risk analysis for investment decisions in agriculture Exchange Trade Funds. Bielinskyi et al. (2021) indicated the instability of the price dynamics of the energy market formed the inadequacy of the quantitative approach for evaluation of pricing processes and could cause abnormal shocks and crashes.

2. METHODOLOGY

The research paper examines the fluctuation of output and energy prices fluctuations as result of shocks influencing economic market. For modeling output and energy price adjustments, we denote Y – the total output of firms; p^e – the equilibrium energy price level that is described as a marginal wage cost. In equilibrium, aggregate demand is related to equilibrium price level and full employment, inflation is equal to expected inflation. The short-term fluctuations of energy price and output are given by system of differential equations

$$p' = \mu\,(D(f(Y), p) - Y), \quad (1)$$

$$Y' = \omega\,(p - mL(Y)) \quad (2)$$

that corresponds with system dynamic model represented in Figure 1. In our research, we consider different type of functions for the marginal wage cost function $f'(Y)$ and aggregate demand function evaluation and take into account possible shocks that disturb output production.

Suppose that gw is the real wage gap; $g\pi$ – gap between the actual inflation and desired level of inflation. The dynamics of wage and inflation gaps is given by the model

$$gw' = \pi, \quad (3)$$

$$g\pi' = \delta(1 - gw^2)\, g\pi - gw \quad (4)$$

The system has singular fixed point $gw^e=0$, $g\pi^e=0$. The linearized system has the following form

$$\begin{pmatrix} gw' \\ g\pi' \end{pmatrix} = \begin{pmatrix} 1 & 0 \\ -(1+2\delta(gw \times g\pi)) & \delta(1-gw^2) \end{pmatrix} \begin{pmatrix} gw \\ g\pi \end{pmatrix} \quad (5)$$

The expansion of system around the equilibrium point is

$$\begin{pmatrix} gw' \\ g\pi' \end{pmatrix} = \begin{pmatrix} 1 & 0 \\ -1 & \delta \end{pmatrix} \begin{pmatrix} gw \\ g\pi \end{pmatrix} \quad (6)$$

The matrix of linearized system

$$D = \begin{pmatrix} 1 & 0 \\ -1 & \delta \end{pmatrix} \quad (7)$$

has two eigenvalues

$$\rho_1 = \left(\delta - \sqrt{\delta^2 - 4}\right)/2, \qquad \rho_2 = \left(\delta + \sqrt{\delta^2 - 4}\right)/2 \quad (8)$$

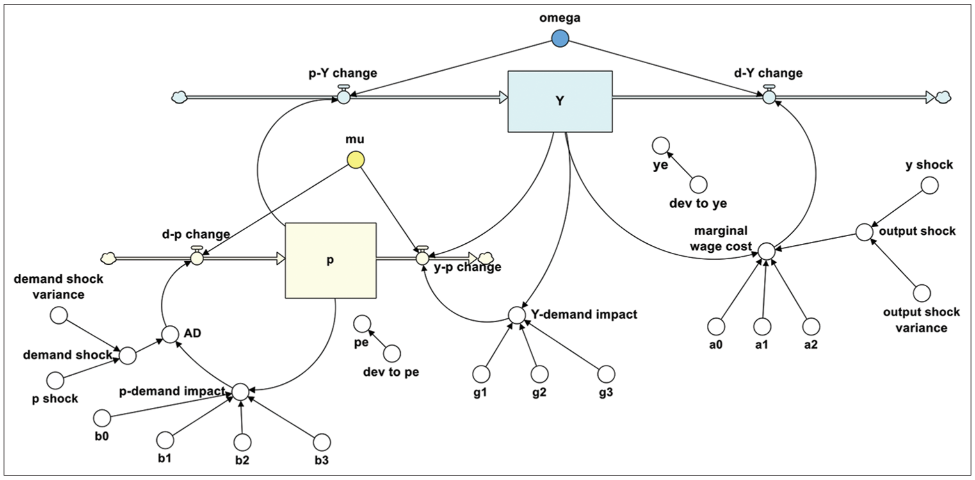
3. RESULTS

We consider different possible combinations of demand and output shocks in model (1) – (2) and represent the impact of market indicators in response to unpredictable disturbances. The sensitivities adjustment are important factors of economic stabilization. Figures 2 and 3 represent the dynamics of output and price fluctuations after simultaneous moderate demand shock and strong output shock for different level of price adjustment for different values of parameter μ.

The greater is sensitivity of price to demand-output gap the larger is the amplitude of fluctuations and less stable are output responses. The price shows very distinguish pattern for different values of adjustment coefficient. Particularly for $\mu = 5$ the price demonstrate the huge uncertainty during the long term that correspond to online shopping price changes that were observed during the pandemics.

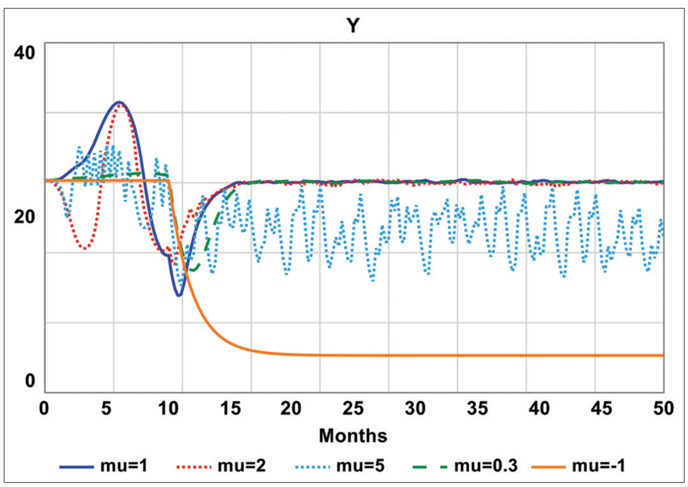
The convergence (Figure 4) reveals a wide range of patterns that depends on sensitivity of price to discrepancy between capacity to

Figure 1: System dynamic model of output and energy prices adjustments to shocks



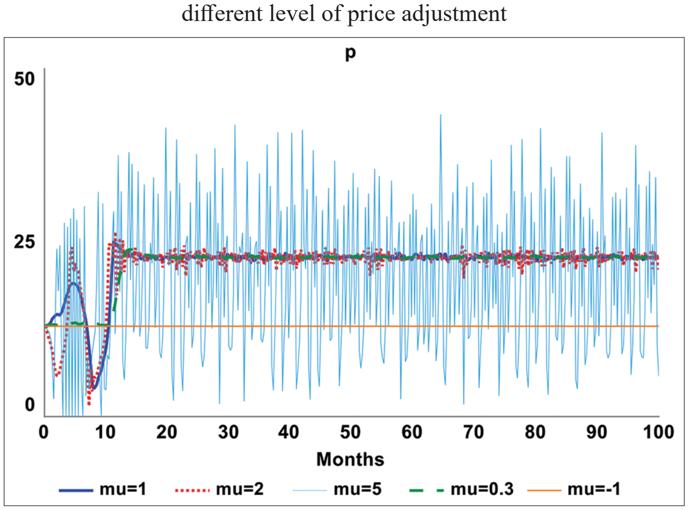
Source: Elaborations of authors

Figure 2: The dynamics of output fluctuation after simultaneous for different level of price adjustment



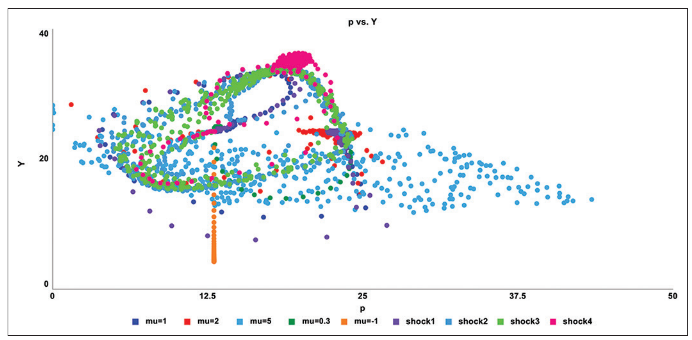
Source: Authors' evaluation

Figure 3: The dynamics of price fluctuation after simultaneous for different level of price adjustment



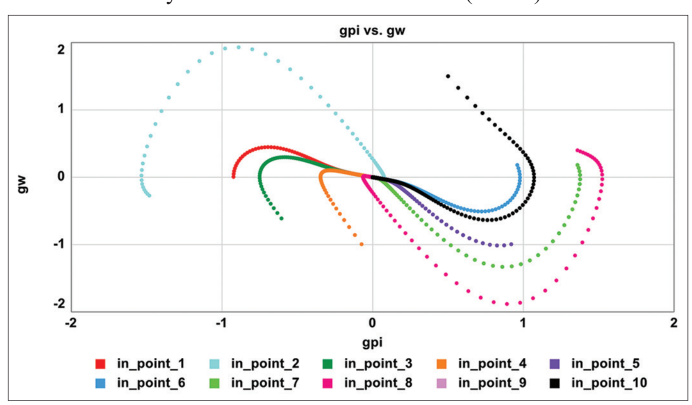
Source: Authors' evaluation

Figure 4: The convergence path of output and price for different level of price adjustment after different shocks



Source: Authors' evaluation

Figure 5: The phase diagram of wage and inflation convergence dynamics in case of stable node (δ = –3)



Source: Authors' evaluation

consume and real output production capability. If sensitivity is not strong, the economics reaches a new steady state much faster. On the other hand, for large price susceptibility the market oscillates for long period after shock occurred and does not characterizes by close restricted area of convergence points. The stronger is shocks the complicated is the convergence path.

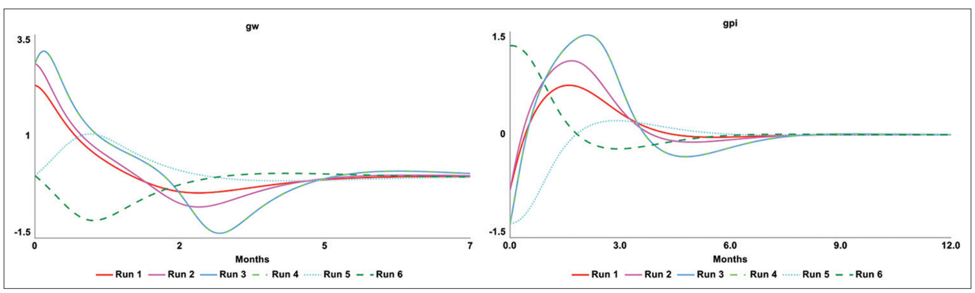
The dynamic properties of system (3) – (4) significantly depend on properties of its eigenvalues. We investigate five different cases starting with the case when δ is negative and next moving of the system along the axis of δ. If $\delta < -2$ both eigenvalues ρ_1, ρ_2 are

Table 1: The simulation results for wage and inflation gaps in case of unstable node

	Parameter's value							
	δ=2.2		δ=3		δ=4.5		δ=6	
	gpi	*gw*	*gpi*	*gw*	*gpi*	*gw*	*gpi*	*gw*
Initial values of system variables								
	0.5000	0.9053	0.5000	0.9053	0.5000	0.9053	0.5000	0.9053
t=1	1.3261	0.1507	1.3830	0.0514	1.4279	–0.1095	1.4368	–0.1636
t=2	0.9607	–0.8054	1.0192	–0.7038	1.1070	–0.5099	1.1765	–0.3651
t=3	–1.1751	–3.9491	–1.2726	–4.9061	–0.8868	–7.0814	0.0776	–4.4773
t=4	–1.9395	0.2995	–1.9568	0.2252	–1.9985	0.1470	–2.0387	0.1072
t=5	–1.5863	0.4210	–1.7061	0.2833	–1.8416	0.1686	–1.9266	0.1177
t=6	–1.0155	0.8404	–1.3656	0.4269	–1.6570	0.2047	–1.8022	0.1323
t=7	1.1042	4.0805	–0.6657	1.3369	–1.4201	0.2826	–1.6597	0.1549
t=8	1.9559	–0.2954	2.0659	0.0508	–1.0251	0.6171	–1.4869	0.1964
t=9	1.6086	–0.4116	1.8705	–0.2426	1.8194	3.6385	–1.2469	0.3091
t=10	1.0591	–0.7928	1.5954	–0.3191	1.9765	–0.1497	–0.6295	1.6218
t=11	–0.8830	–4.0974	1.1871	–0.5584	1.8163	–0.1728	2.0611	–0.1053
t=12	–1.9716	0.2882	–0.1333	–3.5467	1.6262	–0.2123	1.9512	–0.1152
t=13	–1.6305	0.4027	–2.0136	0.2106	1.3768	–0.3032	1.8297	–0.1287
t=14	–1.1003	0.7506	–1.7771	0.2642	0.9237	–0.7806	1.6917	–0.1491
t=15	0.6677	3.9276	–1.4686	0.3718	–2.0698	–0.2839	1.5270	–0.1848
t=16	1.9868	–0.2796	–0.9372	0.8480	–1.9541	0.1525	1.3076	–0.2711
t=17	1.6519	–0.3944	1.7756	2.8670	–1.7904	0.1772	0.8701	–0.8537
t=18	1.1394	–0.7129	1.9319	–0.2302	–1.5941	0.2209	–2.0830	0.1002
t=19	–0.4659	–3.6421	1.6746	–0.2927	–1.3302	0.3285	–1.9752	0.1128
t=20	–2.0015	0.2685	1.3173	–0.4575	–0.7914	1.0590	–1.8565	0.1254

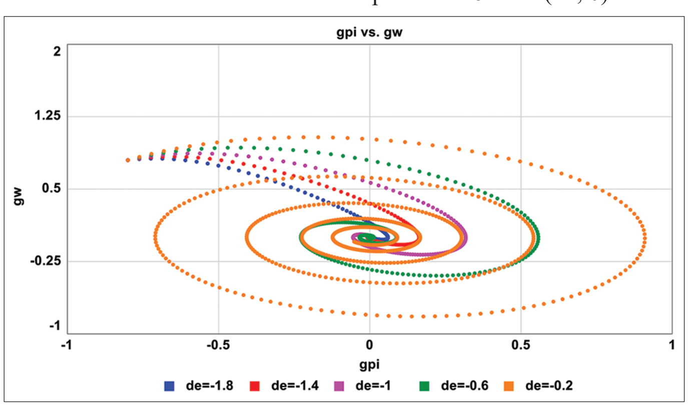
Source: Authors' evaluation

Figure 6: The dynamics of wage and inflation in transion period and steady state from different initial points for δ = –1.5



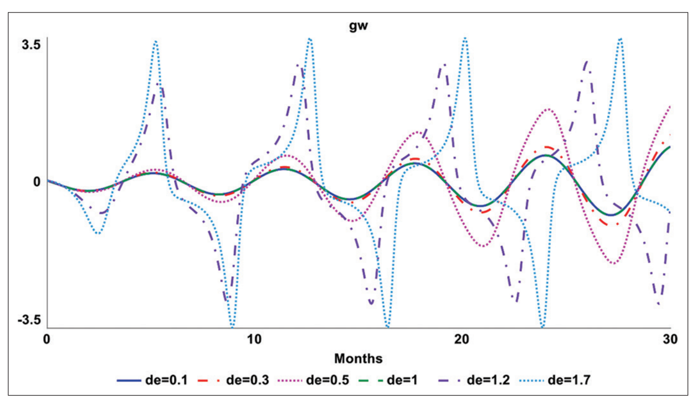
Source: Authors' evaluation

Figure 7: The phase portrait of wage and inflation convergence to a stable focus with various values of parameter δ from (–2; 0) area



Source: Authors' evaluation

Figure 8: The dynamics of wage gap in transitory period for different value of δ in case of unstable focus



Source: Authors' evaluation

real and negative so equilibrium point (0,0) is steady and describes the stable node. Regardless of the initial point the system moves to the equilibrium point where wage gap as well as inflation gap are zero (Figure 5).

If δ is negative but greater than –2 both eigenvalues ρ_1, ρ_2 are complex with negative real parts and variables reach the equilibrium in the long-run (Figure 6). The fixed point describes the stable focus (Figure 7). For δ = 0. The both eigenvalues have zero real parts so are purely imaginary. In this case $\rho_1 = -i$, $\rho_2 = i$ and the fixed point exhibits a center

For positive value of δ the shape of the phase diagram change dramatically and the fixed point becomes unstable. Therefore, the system reveals a bifurcation point at the value $\delta = 0$. If δ is positive and <2, the eigenvalues are complex. Their real parts are positives and fixed point exhibits an unstable focus (Figure 8).

For δ greater than 2 the eigenvalues are real and both positive. The fixed point establishes an unstable node (Table 1) and is determined as a repeller.

4. CONCLUSIONS

These days when we experience many consequences of Covid-19 crisis and even more severe problems caused by war in Ukraine the concern of policymakers in the whole word is real output stability, energy prices predictability, unemployment recovering and providing safe employment. The policy of each country is focused on issues related to mitigation of recession. The situation is unstable and substantive complicated.

It is important that not all output and energy prices movement are undesirable. In the short and medium period, some part of output fluctuation reflect not only demand shocks, lack of flexibility in energy prices and nominal wages, but correspond with changes in growth rate of the productivity and production capacity. Some short run fluctuations are related to changes in technologies, trade conditions, labor force movement. Thus, it is vital for policymakers to be able to minimize fluctuations of output and inflation around their natural trends, as well as around their flexible-price levels.

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