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Chaotic Economic Growth and Investment in Unmanned Aerial Systems: China and Russia

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Abstract: *Originally viewed as a military tool, an unmanned aerial system (UAS), has important economic applications. The economic opportunity for an unmanned aerial system technology is large. The defense sector will remain the largest market for drones. This paper examines the economic growth stability in China and Russia. The basic aim of this paper is to create a relatively simple chaotic economic growth model. Investment in unmanned aerial systems is an important generator of economic growth and economic stability.*

1. INTRODUCTION

Unmanned aerial system (UAS), plays significant economic roles with vast applications in various sectors. Drone technology holds immense economic potential, especially in defence, making it the primary market for these unmanned systems. Investing in UAS is crucial for stimulating economic growth.

According to FAO (2018), the increase in the use of small, unmanned aerial vehicles (UAVs), or drones, for agriculture is very important. Further, drones are used in various fields (the military, humanitarian relief, disaster management, agriculture, etc.).

In 2015, the terms ‘‘fourth agricultural revolution’’ or ‘‘agriculture 4.0’’ were proposed. These terms referred to the impact of sensors, satellites, digital technology, and robotics in agriculture.

According to the EU Commission (2021), North America held the largest drone market share of 25% in the year 2018. Farmers in the European region have been quite open to drones. India, China, South Korea, and Japan are the major countries in the market. Government initiatives, along with technological advancement, are boosting the market.

The economic applications for drone technology are large: (i) topographic survey; (ii) crop area mapping; (iii) monitoring yield, biomass and soil condition; (iv) crop water status; (v) early detection of disease; (vi) farm machinery monitoring, etc. (EU Commission, 2021).

As stated by Kapustina et al. (2021), the USA, China, and France are the biggest producers of commercial drones. The important drone producers are DJI (China), SenseFly / Parrot SA (France), Yuneec (China), and 3D Robotics (USA). The largest demand is made by the USA, China, Russia, Great Britain, Australia, France, Saudi Arabia, India, and South Korea.

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More than 80% of commercial drones in the world are made by Chinese companies. In the early 2000s, unmanned aerial vehicles (UAV) were used mostly by the military. China is a major factor in the global military drone trade. Chinese military drones are produced by state-owned companies, in contrast to commercial drones, whose producers are almost all private companies. However, the government is increasingly involving itself in the commercial drone sector.

According to Ipsos Business Consulting (2019), the adoption of drones in China's agricultural sector is growing at a rapid pace. The number of agriculture drones is estimated to have doubled between 2016 and 2017. As the world's leading manufacturer of civilian drones, drone technology is readily available in China.

The basic aim of this paper is to create a relatively simple chaotic economic growth model that is capable of generating stable equilibrium, cycles, or chaos. Investment in unmanned aerial systems has an important role in this model. In this sense, it is important to analyze the economic growth stability in the period 1990-2023. in Russia and China.

2. THE MODEL

The chaotic economic growth model is presented by the following equations:

$$\frac{Y_{t+1} - Y_t}{Y_t} = \alpha + \beta \, I_t \tag{1}$$

$$I_{t,d} = \gamma \, I_t \tag{2}$$

$$I_{t,d} = \delta \, Y_t \tag{3}$$

with: Y – the gross domestic product (GDP), I – investment, I_d - investment in unmanned aerial systems, α – the autonomous growth rate of the gross domestic product, β - the coefficient that explains the importance of investment for economic growth, γ - the share of investment that is used for investment in unmanned aerial systems, δ - the share of the gross domestic product that is used for investment in unmanned aerial systems.

Now, putting (1), (2), and (3) together we immediately get:

$$Y_t = (1 + \alpha)\, Y_t + \left(\frac{\beta\delta}{\gamma}\right) Y_t^2 \tag{4}$$

Further, it is assumed that the current value of the gross domestic product (GDP) is restricted by its maximal value in its time series. It is important to introduce y as $y = Y / Y^m$, where Y^m is the maximal value of GDP in its time series. Thus y ranges between 0 and 1. Now, the GDP growth rate is

$$y_t = (1 + \alpha) y_t + \left(\frac{\beta\delta}{\gamma}\right) y_t^2 \tag{5}$$

This model given by equation (5) is called the logistic model. Lorenz (1963) discovered this effect - the lack of predictability in deterministic systems. Sensitive dependence on initial conditions is one of the central ingredients of what is called deterministic chaos.

3. THE LOGISTIC EQUATION

It is possible to show that the iteration process for the logistic equation

$$z_{t+1} = \pi z_t (1 - z_t),\ \pi \in [0,4],\ z_t \in [0,1] \tag{6}$$

is equivalent to the iteration of the growth model (5) when we use the identification

$$z_t = -\left[\frac{\beta\,\delta}{(1+\alpha)\gamma}\right] y_t$$

And

$$\pi = (1+\alpha) \tag{7}$$

Using (5) and (7) we obtain:

$$z_{t+1} = -\left[\frac{\beta\,\delta}{(1+\alpha)\gamma}\right] y_{t+1} = -\left[\frac{\beta\,\delta}{(1+\alpha)\gamma}\right]\left[(1+\alpha)y_t + \left(\frac{\beta\delta}{\gamma}\right) y_t^2\right] =$$

$$= -\left(\frac{\beta\delta}{\gamma}\right) y_t - \left[\frac{\beta^2\,\delta^2}{(1+\alpha)\gamma^2}\right] y_t^2$$

On the other hand, using (6) and (7) we obtain:

$$z_{t+1} = \pi z_t (1 - z_t) =$$

$$= -(1+\alpha)\left[\frac{\beta\,\delta}{(1+\alpha)\gamma}\right] y_t \left\{1 + \left[\frac{\beta\,\delta}{(1+\alpha)\gamma}\right] y_t\right\} = -\left(\frac{\beta\delta}{\gamma}\right) y_t - \left[\frac{\beta^2\,\delta^2}{(1+\alpha)\gamma^2}\right] y_t^2$$

Thus we have that iterating (5) is really the same as iterating (6) using (7). It is important because the dynamic properties of the logistic equation (6) have been widely analyzed (Li & Yorke, 1975; May, 1976). It is obtained that: (i) For parameter values 0 $\pi < 1$ all solutions will converge to $z = 0$; (ii) For $1 < \pi < 3{,}57$ there exist fixed points the number of which depends on π; (iii) For $1 < \pi < 2$ all solutions monotonically increase to $z = (\pi - 1)/\pi$; (iv) For $2 < \pi < 3$ fluctuations will converge to $z = (\pi - 1)/\pi$; (v) For $3 < \pi < 4$ all solutions will continuously fluctuate; (vi) For $3{,}57 < \pi < 4$ the solution become "chaotic".

4. EMPIRICAL EVIDENCE

The main aim of this paper is to analyze the economic growth stability in the period 1990-2023. in Russia and China. In this sense, it is important to use the logistic model (8):

$$y_{t+1} = \pi y_t + \upsilon y_t^2 \tag{8}$$

where: $y = Y / Y^m$, Y – the gross domestic product (GDP), $\pi = (1+\alpha)$, $\upsilon = (\beta\,\delta / \gamma)$, α – the autonomous growth rate of the gross domestic product, β - the coefficient that explains the importance of investment for economic growth, γ - the share of investment that is used for investment in unmanned aerial systems, δ - the share of the gross domestic product that is used for investment in unmanned aerial systems.

Now, the model (8) is estimated (see Tables 1-2).

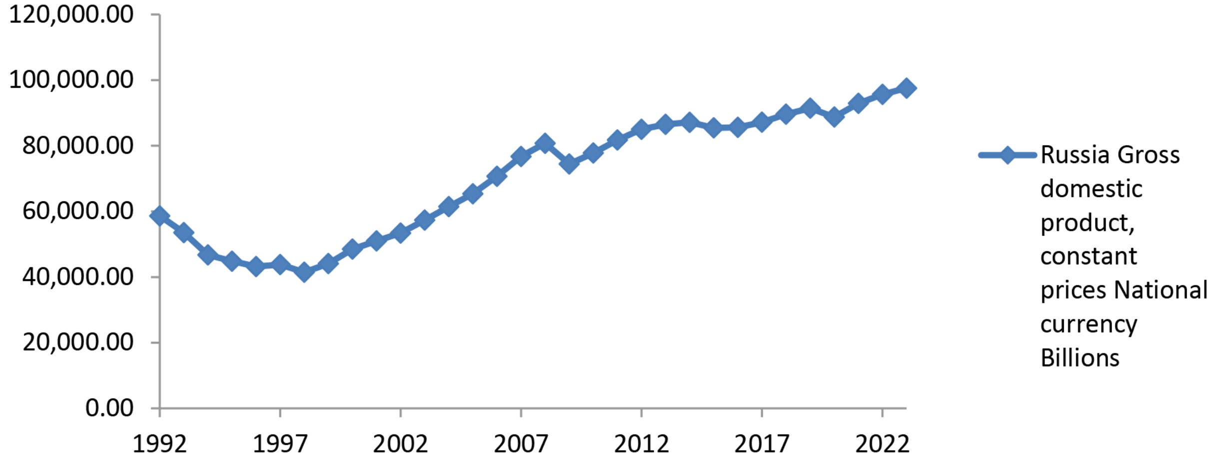

Figure 1. The gross domestic product, constant prices, national currency, billions: Russia, 1990-2023.

Source: IMF, n.d.

Table 1. The estimated model (8): Russia, 1992-2023.

	R=0.98396 Variance explained: 96.818%		
Russia		π	υ
	Estimate	1.03107	0.016529
	Std. Err.	0.04489	0.055099
	t(31)	22.96663	0.299977
	p-level	0.00000	0.766334

Source: Own calculations

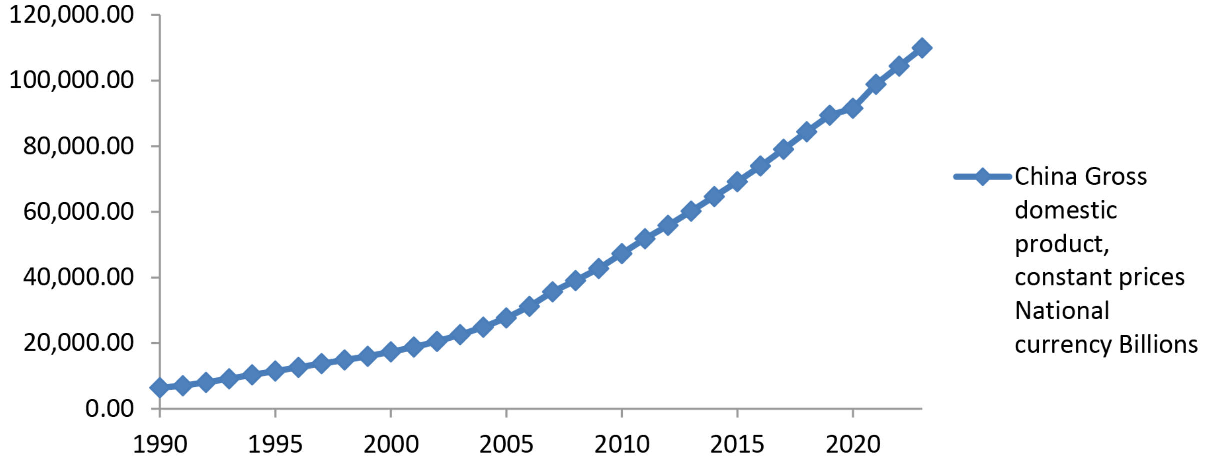

Figure 2. The gross domestic product, constant prices, national currency, billions: China, 1990-2023.
Source: IMF, n.d.

Table 2. The estimated model (8): China, 1990-2023.

	R=0.99911 Variance explained: 99.883%		
China		π	υ
	Estimate	1.11920	0.074659
	Std. Err.	0.01337	0.018366
	t(31)	83.69362	4.065043
	p-level	0.00000	0.000305

Source: Own calculations

The real gross domestic product fluctuated between 58,646.99 and 97,563.46 (unit of measure: national currency in bn, constant prices) in the period 1990-2023 in Russia. π was 1.03107. Further, according to the logistic equation (9), for $1 < \pi < 2$ all solutions monotonically increase in Russia in the observed period.

The real gross domestic product fluctuated between 6,430.86 and 109,933.25 (unit of measure: national currency in bn, constant prices) in the period 1990-2023 in China. π was 1.11920. Further, according to the logistic equation (9), for $1 < \pi < 2$ all solutions monotonically increase in China in the observed period.

5. CONCLUSION

This paper creates the chaotic economic growth model. Investment in unmanned aerial systems is an important part of this chaotic economic growth model. A key hypothesis of this work is based on the idea that the coefficient $\pi= (1+\alpha)$ plays a crucial role in explaining the local economic growth stability, where, α – the autonomous growth rate of the gross domestic product. An estimated value of the coefficient π confirms stable economic growth in Russia and China in the observed period.

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