

**MODELLING AND MANAGING THE EFFECT  
OF TRANSFERRING THE DYNAMICS OF EXCHANGE RATES  
ON PRICES OF MACHINE-BUILDING ENTERPRISES  
IN UKRAINE**

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**Abstract:** The article is devoted to the assessment of the transfer of exchange rates to domestic prices for the products of machine-building enterprises in Ukraine. The study found that the main reason for transferring the dynamics of exchange rates on the prices for the products of machine-building enterprises of Ukraine is a change in production costs for raw materials, resources, and a change in exchange rates. As a model for assessing the degree of transfer of currency rates to the prices of engineering enterprises were chosen the autocorrelation method and the predictive ARIMA model. The ARIMA model allowed detected a time gap between the change in the exchange rate indices and the change in domestic prices for products of Ukrainian machine-building enterprises. It was proposed to take into account in the process of pricing a new factor of influence - "time factor", which takes place in the calculation of prices taking into account the effect of the transfer of exchange rate changes. It was proposed indicators of modified price elasticity coefficients for engineering products depending on the rate of change in exchange rates. The aim of the research is to develop a methodology for modelling and managing the effect of shifting the dynamics of the exchange rates on the prices of the enterprises of machine-building in Ukraine. The main factors that increase the dependence of domestic prices on products of machine-building enterprises from exchange rates are: liberalization of the economy and openness of the machine-building industry for foreign markets; dependence of the raw material and resource base on imported components; increase in the export of machine-building products; weak price differentiation of production of machine-building enterprises.

**Key words:** pricing, the effect of shifting, machine-building enterprises, price indices, exchange rates, ARIMA, Ukraine

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## Introduction

Globalization, as an economic phenomenon, influenced the emergence and spread of the dollarization effect of national economies. The problem of dollarization is associated with the substitution of the functions of money that the national currency performs. The urgency of this problem increases with the replacement of all functions of money by foreign currency and the transition to payment settlements in dollars. The creation of reserves in foreign currency and the use of the dollar as a means of payment in international payments stimulate the process of dollarization. In addition, the official recognition of the US dollar as the national currency by a number of developing countries contributes to the accumulative effect of dollarization and an increase in the dependence of these economies on currency fluctuations. In this regard, the formation of a methodology for modeling and managing the effect of the transfer of exchange rate changes on the domestic prices of enterprises' products acquires great importance.

The dollarization of developing economies is a quite widespread phenomenon. It is being researched from various points of view. It is being accepted as a threat to developing economies (Versal and Stavystkyy, 2015, Contreras et al., 2016) negatively affecting traditional sectors of developing countries' economies, especially agriculture (Vasquez et al., 2018) and other economic sectors of low to medium value added, and locking these countries in a trap of being dependent of only on one core export commodity, which is usually being exported in a raw form, not having produced a value added in a developing country. The parallel currency markets (Pilosof 2009) serve to enrich the small number of people and impoverishes the majority of developing countries citizens widening the GINI gap and severely harming the industries. The dollarization also negatively affects developing countries currencies' ability to automatically adjust to trade shocks or inability to avoid speculative attacks (Frankel, 2012), the inability of seigniorage (Borensztein and Berg, 2000) and asymmetric effects of currency substitution (Samreth and Sok, 2018). The negative aspects of dollarization (partial) are also manifested through lowering the financial depth of developing countries financial system (Bannister et al., 2018).

Although there is a wide spectre of scientific studies about the benefits of dollarization, Bocola and Lorenzoni (2018) point out on the dollarization's influence on the availability of financial capital in developing countries, as it provides a cheaper alternative for high-risk bonds in local currency. It also helps the banks of developing countries to earn higher profit margins (Caglayan and Talavera, 2016), brings stability relatively after turbulent hyperinflation periods (Dekker, 2017), facilitates trade (Surkala and Nicholas, 2016), etc.

In Ukraine, this problem is particularly relevant, especially what concerns machine-building enterprises. It is important to establish the degree of influence of changes in exchange rates on the prices of machine-building enterprises. Explain the main reason for the existence of the transfer effect and what it is.

Thus the purpose of the research is to develop a methodology for modelling and managing the effect of shifting the dynamics of the exchange rate on the prices of the enterprises of machine-building in Ukraine. The object of the study is to assess the prices of finished products of the machine-building enterprises in Ukraine and find out the exchange rate difference. The subject of the study is to simulate the effect of shifting the dynamics of exchange rates on the prices of machine-building enterprises.

### Literature Review

There are different scientific attitudes towards dollarization. Anischenko (2011) treats dollarization as: *“as the process of spreading in a national economy foreign currency as a means of payment and asset formation, accumulation and measure of value, regardless of the degree of full or partial replacement of the national currency in financial calculations”* (Anischenko, 2011). Other scientists have linked this process with complete replacement of the national currency as a means of circulation, payment and measure of value. So, Semenov (2008) and Michalchuk (2016) treating dollarization, focus on the formation of high rates of inflation in countries where dollarization is widespread.

Devereux et al. (2006) has investigated the dependence of prices on the dynamics of exchange rate fluctuations in the domestic markets of developing countries. In turn, Delatte and López-Villavicencio (2012) has conducted a significant study of developed economies and it proves that developed economies also have a dependence on dollarization, which is reflected in the price dynamics of domestic markets of these countries. Dobrynskaya (2008) investigates the effectiveness of monetary policy in terms of price discrimination, which takes place against the backdrop of dollarization of the economy. Piontkovsky (2014) has substantiated the volatility of inflation depending on the degree of dollarization on the example of transition economies, using Thomas's model.

In general, many economists are concerned with the modelling and management problems, but the simulation of the effect of shifting the dynamics of exchange rates on the prices of machine-building enterprises is not sufficiently researched. A lot of scientists include the will of the integrity of exchange rates to risk factors in enterprises or factors that have a significant impact on the change in demand. For example, the research of O. Yashkina defines price risks by using the regression model of dependence of demand on price (Yashkina, 2016). However, the problem of modelling market processes is relevant, but underdeveloped, especially in the context of dollarization issues of the economy.

In recent years the problem of dollarization strengthen national economies becomes relevant also to countries with high standards of economic growth. This problem ceases to be unique to the transition economies. These trends are exacerbated by the use of the dollar as the main reserve currency by most countries all over the world. According to statistics from the latest research in this area, today in the world's foreign exchange reserves accumulated dollar money supply twice as much

as the mass of commodities. All these facts indicate the need for research in the field of economic causes of dollarization and assessing the extent of its influence on various sectors of the economy of Ukraine. The relevance of the study of this problem is also confirmed by the fact that, in many countries there is recognition and dissemination of the dollar as a second currency.

According to the IMF, seven countries have been using the dollar as the official currency in settlements alongside national currencies. In twelve countries of the world, the share of foreign currencies in official transactions and calculations are ranged from 30% to 50% (Piontkovsky, 2014).

In the context of the increasing impact of dollarization on the economic situation of developing countries, the choice of methodology for assessing such influence becomes relevant. Based on a wide literature review on a dollarization effect, the authors of the present study have created a methodological approach for modelling the effect of the transfer of exchange rates on prices for products of machine-building enterprises.

### Methodology

The study used the general scientific methods of theoretical and empirical research. A systematic approach was used to justify the system of indicators assessing the impact on the degree of dollarization of the economic system of national economies. The method of autocorrelation was used to simulate the effect of the transfer of exchange rates to the internal prices of the machine-building enterprise. Vector Autocorrelation (VAR) and ARIMA models were used to assess the degree of effect of the transfer of dynamics of exchange rate changes to domestic prices for products of machine-building enterprises.

The ARIMA model is used to describe the dynamics of time series that have homogeneous nonstationarity and can be described using approaches that are applicable to stationary rows. It has been used in quite exact meteorological forecastings (Valipour, 2015), energy consumption (Yuan et al., 2016; Ozturk and Ozturk, 2018), agricultural prices (Jadhav et al., 2017), water resources management (Wang et al., 2015), epidemiology (Liu et al., 2016), commodities, stock price (Pai and Lin, 2005; Guha and Bandyopadhyay, 2016) and traffic flow (Kumar and Vanajakshi, 2015) predictions. The ARIMA model uses structural time-series analysis methods. These methods, in contrast to non-structural, are oriented towards the estimation of a small number of parameters in the presence of additional assumptions about the properties of the quantities being investigated.

The studies of the dollarization show that dollarization has a manifestation by showing the effect of transferring the dynamics of exchange rate changes to the domestic prices of the enterprise.

The most accurate definition of the effect of exchange rate transfer is given in the scientific work of Goldberg and Knetter (1997) as, *"The effect of the transfer of exchange rates is manifested in the change in the price of imported products depending on the change in the exchange rate of payments, expressed as*

a percentage. This relationship is expressed in terms of the exchange rate variation between the exporting country and the importing country".

When the price level is completely dependent on the exchange rate, the full transfer effect is manifested (at 100% or  $E = 1$ ), which indicates a single elasticity of domestic prices at the exchange rate. With an incomplete effect of the transfer of exchange rate changes to domestic prices, elasticity is less than 100% or  $E < 1$ .

Based on this approach, under the effect of transferring the exchange rate to the domestic prices of enterprises, it is understood that the degree of sensitivity of the price is changed to 1% in the exchange rate. If there is a complete transfer of the exchange rate to domestic prices, then there will be complete price elasticity depending on the exchange rate that can be expressed by the following coefficient (1):

$$\varepsilon = \left| \frac{\Delta P}{\bar{P}} \div \frac{\Delta K}{\bar{K}} \right|, \quad (1)$$

where:  $\Delta P$  – changes in domestic prices;  $\bar{P}$  – average value of domestic prices,  $\bar{P} = (P_1 + P_2)/2$ ;  $\Delta K$  – differences in foreign exchange rates;  $\bar{K}$  – average value of exchange rates for the period,  $\bar{K} = (K_1 + K_2)/2$ ;

Large currency fluctuations stimulate the growth of prices for imported goods and products that contribute to the demand of consumers switching domestic goods-analogues or their substitutes. To measure the degree of interchangeability of goods of Ukrainian production and their import substitutes or analogues, using a modified coefficient of cross-elasticity of demand, which is determined by the following formula (2):

$$\varepsilon = \left| \frac{P_i}{Q_i} \div \frac{\Delta Q_i}{\Delta P_i} \right|, \quad (2)$$

where:  $Q_i$  – sales of domestic goods product group in the commodity market;  $\Delta Q_i$  – change in the volume of domestic goods of this product group in the commodity market;  $P_i$  – the price of the imported product in this commodity market;  $\Delta P_i$  – increase the price of imported goods in this product market.

Cross-elasticity coefficient shows the percentage change in demand for domestic goods while increasing the price of imported goods due to the increase in the exchange rate.

The calculation of autocorrelation was carried out for the enterprises of carriage building on the basis of the average weighted price data on the products of these enterprises and the dynamics of exchange rate changes using the statistical package of SPSS. For the calculation, the data were taken for 11 years on a quarterly basis with a lag quarter for the period from 2007 to 2018 years. Data on changes in the dynamics of exchange rates were used on the basis of information provided on the

website of the Ministry of Finance of Ukraine (Ministry of Finance of Ukraine, 2018). Calculation of data with a lag in the 1st quarter is obligatory since the calculations confirm that enterprises need some time to react in price changes, which is rather slow.

In order to determine the randomness of data, the Box-Leung test is used, which involves the nomination of two competing hypotheses:  $H_0$ : data is random (that is, white noise).  $H_1$ : Data is not random. The statistical test was carried out according to the following formula (3):

$$\bar{Q} = n(n+2) \sum_{k=1}^m \frac{P_k^a}{n-k} \quad (3)$$

where:  $n$  – number of observations;  $P_k^a$  – autocorrelation  $k$ -th order;  $m$  – the number of lags that are checked.

For this process, it also assumes the independence of the variables (white noise).

For this case, the first hypothesis is confirmed, the data are random variables; that is, it is possible to use the ARIMA model. In the model of autoregression (AR), each value of the series is linearly dependent on the previous values. The general view of the model of autoregression of the  $r^{\text{th}}$  order - AR (p) can be expressed by the following equation (4):

$$y_t = \beta_1 y_{t-1} + \beta_2 y_{t-2} + \dots + \beta_p y_{t-p} + \varepsilon_t \quad (t=1,2,\dots,n)$$

where:  $\beta_1, \beta_2, \dots, \beta_p$  – somewhere constants;  $\varepsilon_t$  – random errors that make up "white noise":  $M(\varepsilon_t) = 0$

AR (p) – model describes the investigated process at time  $t$  depending on its values at previous moments  $t-1, t-2, \dots, t-p$ .

Construction of the model AR (p) of the form (3), which is adequate to the real-time series  $y_t$ , involves the solution of two interrelated tasks: the definition of the rational order of the model (the value of p) and the evaluation of its coefficients. Considering the first general approaches, the parameters of the model AR (p) are estimated.

Without limiting the generality, it assumes that the mathematical expectation of the series  $y_t$  is zero, that is,  $M(y_t) = 0$ . Otherwise, instead of the variable  $y_t$ , in the expression (4) we can consider the centered variable  $\hat{y}_t = y_t - \bar{y}_t$ , where:

$$\bar{y}_t = \frac{\sum_{t=1}^n y_t}{n} = M(y_t), \quad M(\hat{y}_t) = M(y_t - \bar{y}_t) = M(y_t) - M(\bar{y}_t) = M(M(y_t)) = M(y_t) - M(y_t) = 0$$

which proves our assumption.

## Study Results

As can be seen from the results of the calculations presented in Table 1, the coefficients of the lag correlation have significance to the 8th level. For this

process, the independence of the variables (white noise) is assumed. The construction of autoregression and results are presented in Table 1.

**Table 1. Autocorrelation for the average price (AP) in the field of mechanical engineering and currency rates (CR) in Ukraine**

lag	Coefficients of AR (AP)	Standard error	Value (AP)	Coefficients of AR (CR)	Standard error	Value (CR)
1	945	141	44.72	937	141	43.99
2	891	140	85.34	875	140	83.18
3	832	138	121.61	812	138	117.67
4	771	137	153.46	741	137	147.08
5	707	135	180.89	665	135	171.31
6	642	133	204.04	583	133	190.42
7	573	132	222.95	502	132	204.92
8	504	130	237.98	422	130	215.44
9	432	128	249.26	344	128	222.63
10	358	127	257.24	269	127	227.14
11	282	125	262.32	193	125	229.51
12	222	123	265.57	127	123	230.57
13	167	122	267.46	59	122	230.80
14	117	120	268.42	-7	120	230.81
15	66	118	268.74	-74	118	231.20
16	22	119	268.77	-112	116	232.13

The above presented table is evidenced by the indexes of the Box-Leung statistics, which is equal to zero. These statistical values are confirmed not by the stationarity of the time series being studied and the possibility of using the ARIMA model to predict the transfer of exchange rates to domestic prices for machine-building products. It is based on the asymptotic approximation using X2.

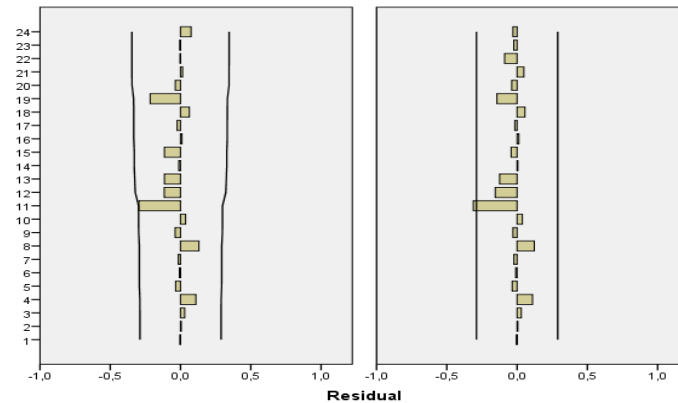
According to the weighted average price and currency dynamics, the ARIMA model was developed using the SPSS package. The results of the statistics are presented in Table 2. According to the characteristics of the coherence of the main indicators of statistical significance, the ARIMA model is adequate to determine the relationship between the dynamics of exchange rates and the domestic prices of carriage enterprises. Charts of autocorrelation and a partial auto-correlation are presented in Figure 1.

**Table 2. Characteristic and consistency of ARIMA model statistics**

Model number		VAR00001		Model_1		ARIMA(2,1,0)(0,0,0)		
Consistency Statistics	Stationary R-square	R-square	Square root of the mean square error	Mean REM *	Max. REM	Average EM*	Max. EM	NBIC *
Percentile (5-95)	0.06	0.98	4285.71	4.51	52.46	2368.53	16470.67	17.14



\*(R)EM – (Relative) error modulus; NBIC - Normalized Bayesian Information Criterion



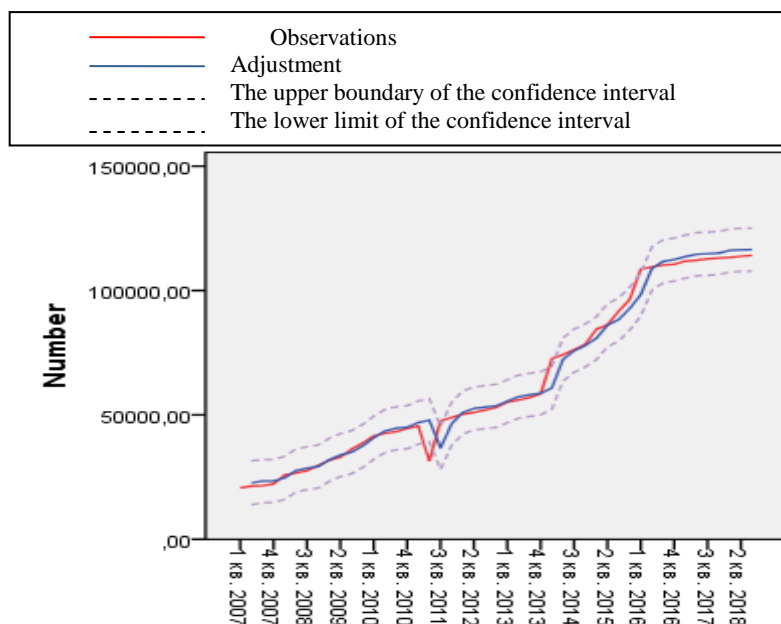
**Figure 1. Charts of autocorrelation and private autocorrelation**

The autocorrelation and frequent autocorrelation graphs show that the values of autocorrelation coefficients are different from zero, which corresponds to the correct choice of the ARIMA model. According to the Ljung–Box test, the hypothesis of the randomness of the data has been analyzed and representing a white noise is confirmed.

This test confirms the statistical significance and the probability of using the ARIMA model to predict the relationship and the effect of the exchange rates on the domestic prices of wagon-building enterprises. The effect of transferring the influence of the dynamics of exchange rates on the domestic prices of wagon-building enterprises is also confirmed by the graph in Figure 2.

This Figure 2 shows the effect of the exchange rate transfer on the price change for the products of engineering enterprises. In general, the ARIMA model makes it possible to predict further changes in the effect of the transfer of exchange rate on the prices of products of machine-building enterprises. The present findings contribute to currency substitution theory, which postulates, what market players choose to denominate their products by foreign currency by trading off the purchasing power risk of domestic currency versus the transaction costs of using foreign currency (Jaber and Jaber, 2017; Malindretos and Tsanacas, 2019).





**Figure 2. The effect of transferring the dynamics of exchange rates on domestic prices of wagon-building enterprises**

We found, what dollarization comes as a protective effect of firm not only to a unsound economic policy of a country, complementing Mari del Cristo and Gomez-Puig (2016), Corbo (2017) but also a tool to reflect the World prices in a particular segment, complementing Horton et al. (2016) with evidence from heavy industry segment in Eastern Europe.

### Managerial Implications

As study shows, the Box-Jenkins methodology is a potent tool for accurate short-term forecasting. It could be a weapon of choice for senior-level managers trying to predict the influence of prevailing currents in a financial market (our case – dollarization effect) to the end price of their products and to adjust their pricing decisions according to these findings. Indirectly it also helps to forecast production quantities more precisely, as estimating indirect effects of changes in global financial markets and its impact onto the final price of a product paid by the consumer, helps to adapt to deviations in a supply-demand balance more accurately. Although this method has its drawbacks, managers should take into account that the creation of a satisfactory ARIMA model according to the Box-Jenkins method requires a rather large amount of historical data and a considerable amount of analyst's time.

## Conclusions

The article examines the effect of transferring the dynamics of changes in exchange rates on the price of products of engineering enterprises of Ukraine. The paper proves the possibility of using the ARIMA model to predict the onset of the effect of currency exchange rates on the prices of products of machine-building enterprises. The practical application of the ARIMA forecasting model made it possible to identify gaps in time between the changes in exchange rate indices and the dynamics of domestic prices for products of machine-building enterprises. This indicates the presence of a time lag between the dynamics of currency exchange rates and price changes. The main factors determining the degree of influence of the effect of the transfer of exchange rates on the prices of machine-building enterprises, among which, the greatest influence, are as follows: degree of openness of the industry to external markets and dependence on import resources; high share of exports in the structure of manufactured goods; low degree of differentiation of products of machine-building enterprises; discriminatory prices for consumers. Prospects for further research in this direction may be the use of the method of modeling the effect of transferring the dynamics of the exchange rate on the prices of enterprises in other sectors of the national economy, with subsequent determination of their greatest dependence on exchange rate fluctuations.

## Study Limitations

The main study limitation lays in fact that the overall effect of the forecasts of prospects based on time series is based on the assumption that the development of future events will be like the past, and the structure of past events lends itself to an adequate description. As a result of the study, factors that influenced the emergence and spread of the effect of transferring exchange rate changes on the prices of products of machine-building enterprises were identified. It was concluded that the main factors of such influence are the following: the liberalization of the economy and the openness of the engineering industry for international markets; the ratio between the volumes of imported and exported products; strengthening the national currency by increasing exports.

However, this effect may have the opposite effect on exporters, since price restrictions in foreign markets will affect the pricing in the domestic markets for machine-building products. Manufacturers of export products will seek to offset costs by increasing domestic prices, which will affect the projected price transfer effect. Thus, the following law comes into force: the lower the share of exported goods, the higher the indirect influence of exchange rates on domestic prices for machine-building products.

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#### MODELOWANIE I ZARZĄDZANIE EFEKTAMI TRANSFERU DYNAMIKI KURSÓW WYMIANY NA CENY PRZEDSIĘBIORSTW BUDOWY MASZYN NA UKRAINIE

**Streszczenie:** Artykuł poświęcony jest ocenie transferu kursów walutowych na ceny krajowych produktów przedsiębiorstw budowy maszyn na Ukrainie. Badanie wykazało, że głównym powodem przeniesienia dynamiki kursów wymiany na ceny produktów przedsiębiorstw budowy maszyn na Ukrainie jest zmiana kosztów produkcji surowców, zasobów, zmiana kursów walut. Jako model do oceny stopnia transferu kursów walut do cen przedsiębiorstw inżynieryjnych wybrano metodę autokorelacji i predykcyjny model ARIMA. Model ARIMA pozwolił wykryć lukę czasową między zmianą wskaźników kursu walutowego a zmianą cen krajowych produktów ukraińskich przedsiębiorstw budowy maszyn. Zaproponowano uwzględnienie w procesie wyceny nowego czynnika wpływu - „czynnika czasu”, który ma miejsce przy obliczaniu cen z uwzględnieniem efektu

przeniesienia zmian kursu walutowego. Zaproponowano wskaźniki zmodyfikowanych współczynników elastyczności cen dla produktów inżynierskich w zależności od tempa zmian kursów wymiany. Celem badań jest opracowanie metodologii modelowania i zarządzania efektem transferu dynamiki kursów walutowych na ceny przedsiębiorstw budowy maszyn na Ukrainie. Głównymi czynnikami zwiększającymi zależność cen krajowych od produktów przedsiębiorstw przemysłu maszynowego od kursów walutowych są: liberalizacja gospodarki i otwartość przemysłu budowy maszyn na rynki zagraniczne; zależność surowców i zasobów od importowanych komponentów; wzrost eksportu produktów do budowy maszyn; słabe zróżnicowanie cenowe produkcji przedsiębiorstw budowlanych.

**Słowa kluczowe:** wycena, wpływ przesunięć, przedsiębiorstwa przemysłu maszynowego, wskaźniki cen, kursy walut, ARIMA, Ukraina

### 交易动态转移对乌克兰机械制造企业价格影响的建模与管理

**摘要:** 本文致力于评估乌克兰机械制造企业产品的汇率与国内价格的转移。由于对乌克兰机器制造企业价格转移指标的高价值的研究得出了结论，这证实了乌克兰经济对美元汇率的高度依赖性。这表明乌克兰经济基本部门的高度美元化，其中包括机器制造企业。该研究发现，将汇率动态转换为乌克兰机器制造企业产品价格的主要原因是原材料，资源的生产成本和汇率变化的变化。作为评估货币汇率向工程企业价格转移程度的模型，选择了自相关方法和预测ARIMA模型。

ARIMA模型允许检测到汇率指数变化与乌克兰机器制造企业产品国内价格变化之间的时间差。建议在定价过程中考虑一个新的影响因素

“时间因素”，它考虑到汇率变动转移的影响，在计算价格时发生。根据汇率的变化率，提出了工程产品的修正价格弹性系数的指标。自相关用于进一步确定所选模型的正确性，这证实了所选模型的充分性。还观察到了第二阶的平稳性。该研究的目的是开发一种方法，用于模拟和管理将汇率动态转变为乌克兰机器制造企业价格的影响。

增加国内价格对机器制造企业产品的汇率依赖的主要因素是：经济自由化和国外市场机械制造业的开放性；原材料和资源基础依赖进口零部件；增加机械制造产品的出口；机械制造企业生产价格差异较弱。

**关键词:** 定价，转移效应，机器制造企业，价格指数，汇率，ARIMA，乌克兰