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Analysis of the Competitive Environment in the Electronics Market: the Global Crisis of the Semiconductor Industry and Global Development Trends

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Abstract. The relevance of the study lies in the large-scale and progressive impact of the shortage in the semiconductor market on the key industries of modern electronics production. Currently, the production of microchips shows the highest growth rates, the sphere is directly associated with the fourth industrial revolution, so leading manufacturers are actively seeking either to increase market share or to gain leadership altogether. As a result, competition is intensifying both between individual companies and between countries. The purpose of the study is to determine the degree of influence of the shortage of semiconductors on the final cost of goods based on microchips. The main task is to analyze the dependence of the cost of video cards on the cryptocurrency exchange rate, the growth in demand for the extraction of which is one of the factors that influenced the semiconductor crisis. The article analyzes the current state of the semiconductor industry market, describes the key players, manufactured products by type. The chronology of events that led to the shortage of microchips – the main basis for any modern electronics – has been built. The article describes the main affected industries from the crisis in the semiconductor market, analyzes the consequences in quantitative and qualitative terms. Conclusions are drawn about the global role of cryptocurrency mining in the progressive shortage of microchips. In the course of the study, general scientific methods were applied, such as analysis, synthesis, comparison, as well as special methods (statistical-economic and econometric analysis). A paired linear regression model is constructed to identify the relationship between the Bitcoin exchange rate and the cost of popular video card models. As a result of the study, the relationship between the cryptocurrency exchange rate and the price of video cards was determined, and the stock index of the semiconductor industry was analyzed.

Keywords: microchips, shortage of semiconductors, video cards, cryptocurrencies, correlation-regression analysis, increase in prices for electronics, the competitive war between the United States and China

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Анализ конкурентной среды на рынке электроники: мировой кризис полупроводниковой промышленности и глобальные тенденции развития

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Аннотация. Актуальность исследования заключается в масштабном и прогрессирующем влиянии дефицита на рынке полупроводников на ключевые отрасли производства современной электроники. В настоящее время производство микрочипов показывает наибольшие темпы роста; сферу напрямую связывают с четвертой промышленной революцией, поэтому ведущие производители активно стремятся либо увеличить долю рынка, либо вовсе завоевать монополистическое лидерство. Как следствие, усиливается конкурентная борьба и между отдельными компаниями-производителями, и между странами. Цель исследования – определение степени влияния дефицита полупроводников на конечную стоимость товаров, основой которых являются микрочипы. Основной задачей является анализ причин дефицита микрочипов и его последствий. В статье проанализировано современное состояние рынка полупроводниковой промышленности, описаны ключевые игроки, производимая продукция по типам. Выстроена хронология событий, повлекших за собой дефицит микрочипов – основы любой современной электроники. В статье описаны основные пострадавшие отрасли от кризиса на рынке полупроводников, проанализированы последствия в количественном и качественном выражении. Сделаны выводы о глобальной роли майнинга криптовалют в прогрессирующем дефиците микрочипов. В ходе исследования были применены общенаучные методы, такие как анализ, синтез, сравнение, а также специальные методы (статистико-экономический и эконометрический анализ). Построена модель парной линейной регрессии для выявления связи между курсом Биткоина и стоимостью популярных моделей видеокарт. В качестве результата исследования определена связь между стоимостью видеокарт как устройств, в комплектации которых используется крупная доля производимой полупроводниковой продукции, и Биткоина, спрос на добычу которого является одним из факторов, повлиявшим на кризис полупроводников, а также проанализирован биржевой индекс полупроводниковой индустрии.

Ключевые слова: микрочипы, дефицит полупроводников, видеокарты, криптовалюты, корреляционно-регрессионный анализ, повышение цен на электронику, конкурентная война между США и Китаем

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Introduction

Microchips and microcircuit are primarily associated with computer processors, video cards and other PC components. However, in the modern world, microchips had become a fundamental element of almost all manufactured electronics: smartphones, mobile workstations, household appliances, cars and many others long ago.

The coronavirus pandemic has become a catalyst for many profound structural changes in most areas of the modern economy. The problems were particularly emerged in the global semiconductor market, which led to failures in the production of equipment running on microchips.

K. M. Kuzin, E. V. Erokhina, D. I. Meerovich, O. B. Shilovich, V. Chernykh paid attention to the assessment of global trends in the electronics market related to the crisis in the semiconductor industry market in their scientific works.

The semiconductor industry is rapidly developing, in 2021 it showed one of the highest growth rates. Currently, the world leader in the production of semiconductors is the largest Taiwanese company – Taiwan Semiconductors Manufacturing Company (TSMC), which has a market share of about 54%. All innovative developments in the production of microchips often belong to TSMC. The South Korean company Samsung is the second largest in the market – its share is about 17%. Global foundries, UMC, and TSMC also hold significant market shares. The remaining part of the market is distributed among smaller players [10].

The companies carry out production according to the technical documentation of customers, microcontrollers, microprocessors, memory microchips and a number of other components that are later used in the assembly of modern electronics. Table 1 shows how the structure of capital expenditures has changed in the period from 2019 to 2021.

According to table 1, capital expenditures in 2021 in the field of semiconductor production increased by almost 50% compared to 2019, mainly due to the expansion of semiconductor production according to customer technical documentation, DRAM/SRAM and MPU/MCU production.

According to the data presented in table 1, about a third of the world's semiconductor production (34.2%) is accounted for by memory chips (DRAM/SRAM and Flash/Non-volatile), which are directly involved in the creation of video cards, as they are an integral part of them. Semiconductor manufacturers often prefer the production of chips for video cards as a more profitable segment in accordance with a cost-oriented approach to business [1, 4]. In addition to the benefits, microprocessors for cars have requirements that are more stringent in subsequent operation: from operation in various temperature conditions to service life.

Despite TSMC's indisputable leadership in the semiconductor market at the moment, China, the USA and South Korea intend to significantly expand their influence in

Table 1. Semiconductor industry capital spending from 2019 to 2021, by product type

Types of semiconductor industry products	2019		2020		2021	
	Billions dollars	% of total	Billions dollars	% of total	Billions dollars	% of total
Production of semiconductors according to technical documentation of customers	26.2	25.6	37.3	33.0	53	34.9
Flash/Non-volatile	22.6	22.1	24.6	21.8	27.9	18.4
DRAM/SRAM	19.1	18.7	17.9	15.8	24	15.8
MPU/MCU	16.9	16.5	16.5	14.6	23.5	15.5
Logic integrated circuits	8.5	8.3	8.8	7.8	12.4	8.2
Analogs/other	9	8.8	7.9	7.0	11.2	7.4
Total	102.3	100	113	100	152	100

Source: https://www.statista.com/statistics/1055209/capital-spending-in-the-semiconductor-industry-by-product-type-worldwide/

the market in the long term. Intel plans to significantly increase its production capacity in the next 4 years with government support. The main goal of the American company is to catch up and get ahead of TSMC and Samsung technologies. China does not stand aside either – SMIC planned to significantly increase production in 2021 by purchasing new equipment, but the equipment could not be obtained due to sanctions. Despite the setback, the company continued to work on semiconductor technologies. The South Korean company Samsung has set a goal to become the leader of the semiconductor industry by 2030. To fulfill it, in May 2021, representatives of the company announced the investment of 17 billion dollars in the construction of a new plant in the United States. Another South Korean manufacturer SK hynix is considering the possibility of acquiring Key Foundry. Europe will also join the competition in the near future – the European Commission has promulgated the "Law on Chips". It implies stimulating the production of semiconductors by attracting 49 billion public and private investments.

The development of the semiconductor industry for these states is currently key, since it is with the production of semiconductors that the fourth industrial revolution is associated. Key player countries are striving to capture the largest market share in order to attract manufacturers of complete equipment as customers on a large scale. Thus, Taiwan, the USA, China and South Korea have entered into a large-scale competitive race, which forces manufacturers to increase capacity through the construction of new factories, mergers and the invention of unique technologies.

Causes of microchip shortage and its consequences

The global shortage of microchips was provoked by a chain of events that overlapped one another in 2019–2021. Increasing demand for personal computers during the lockdown period, natural disasters, the competitive war between the US and China in the semiconductor market, a surge in demand for video cards for mining caused serious disruptions in the smooth production processes of semiconductor companies.

So, at the beginning of 2021, abnormal frosts and snow storms hit all industries in Texas. Due to icing, power lines were out of order, the operation of wind farms, which are the basis of the generating capacities of Samsung, NXP, and Infineon factories, stopped. Samsung's Texas factories account for about 28% of the company's total capacity, a week-long shutdown of which led to a loss of 1–2% of semiconductors produced globally.

In March 2021, a devastating fire broke out at the largest Renesas Electronics plant in Japan, which disabled the unique equipment that produces automotive microchips. The fire cost the global auto industry a 7% annual production cut.

But the Taiwan drought in the spring of 2021 caused the greatest damage to global microchip production. The specificity of microchip production is the use of a large amount of water in the production process. The worst drought in a quarter of a century forced the Taiwanese government to impose severe restrictions on water consumption by factories. Therefore, the Taiwanese factories TSMC, UIS, PSMC, loaded with orders, occupying about 68.9% of the world market for the production of semiconductors, are forced to reduce the streaming production of microchips to a minimum until July 2021.

Intensified competition for technological leadership between the US and China has exacerbated the situation in the microchip market. In recent years, a real competitive war has developed in the electronics industry. The US aims to remain the world leader in the technology sector. In its turn, China is rapidly developing in the field of scientific research, ranking second in the world – more than 20% of all global spending. The successful development of the Chinese semiconductor industry is an aggravating element in the trade war between the US and China. The

globalization of the economy makes enterprises face the inevitability that they will have to operate in a tough competitive environment both in the domestic and foreign markets [5]. Under the current conditions, the theoretical canons of competition cease to work, since here we are not talking about competition in its pure form, but a competitive struggle is manifested in which each player monopolizes a market share. In such attempts to achieve the goal, purely market methods fade into the background, giving way to political games [3].

The policy of geopolitical pressure was chosen by the United States in relation to China, the purpose of which was to limit the transfer of advanced technologies to Chinese semiconductor production. One of such cases of state pressure was the situation with the suspension of the license for the use of advanced equipment for EUV lithography, previously issued to a Chinese customer by the Dutch company ASML. The US government played a direct role in telling Dutch officials about the possible negative consequences in the relationship between these countries, if the equipment is transferred to China. And this case is not isolated. Under the pretext of a national security threat, the US government has imposed severe sanctions on Chinese semiconductor companies SMIC and Huawei. The sanctions consist of banning Chinese companies from using American production technology, as well as stopping the supply of equipment. In addition, TSMC was dictated by the decision to end contract manufacturing for Huawei. Therefore, before the sanctions came into force, Chinese companies sharply increased purchases of chips, building up stocks to reduce the risks of disrupting supply chains. Accordingly, the supply of microchips has significantly decreased due to the rapid purchase of chips by Chinese companies. Thus, not classical market, but geopolitical (unfair) competition has become one of the factors in the growing shortage of microchips.

During the lockdown period, the demand for personal computers, laptops, game consoles, smart devices that require access to the Internet has grown significantly. Global production of personal computers in 2020 increased by 12.0% compared to 2019, in 2021 by 14.4% compared to 2020. During the time period from the beginning of 2020 to 2022, PC production increased by more than 28%. The dynamics of deliveries of personal computers over the past 8 years is shown in figure 1.

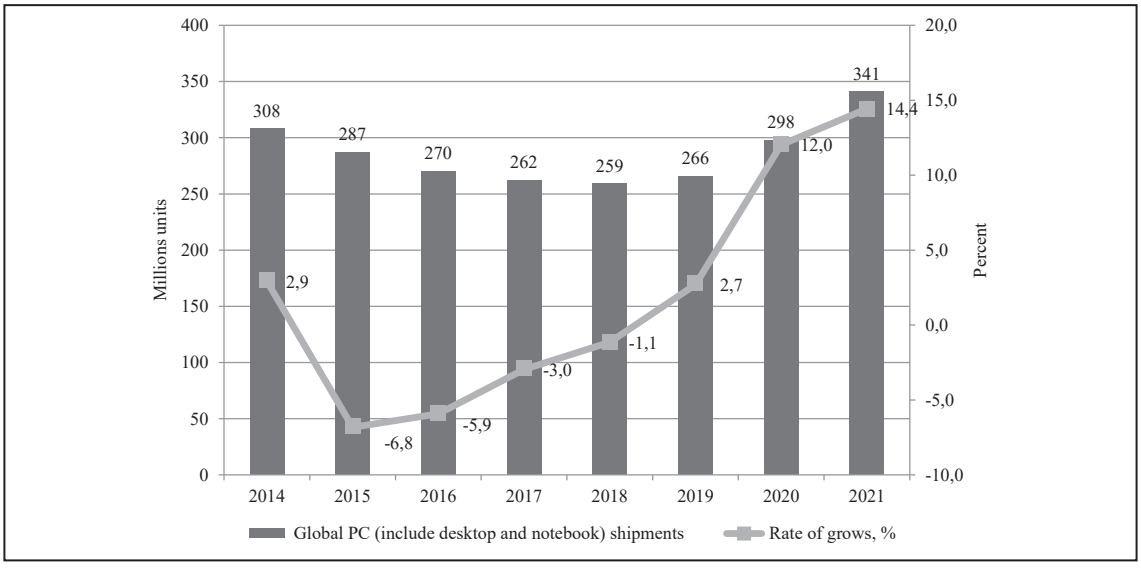
Accordingly, the growth of sold computers requires the supply of more components to manufacturing companies. In addition to the growth in demand for PCs, the consumer electronics industry is rapidly increasing the production of equipment based on integrated circuits, which requires a certain component base.

At the beginning of the pandemic, study, work, and communication almost completely switched to the Internet format, which led to a rapid surge in the consumption of network traffic. Fixed Internet traffic grew by 35 percent in 2020, the biggest increase in five years. This provoked providers to expand the fleet of their equipment, which also operates on chips.

Because of the increase in demand for chips, the waiting time for chips in 2021 increased to 18 weeks, which is 4 weeks more than the previous crisis peak in 2018. Sectors of the industry are currently facing increasing order delays due to shortages of microchips needed to manufacture products. The waiting schedule for chips by companies is shown in figure 2.

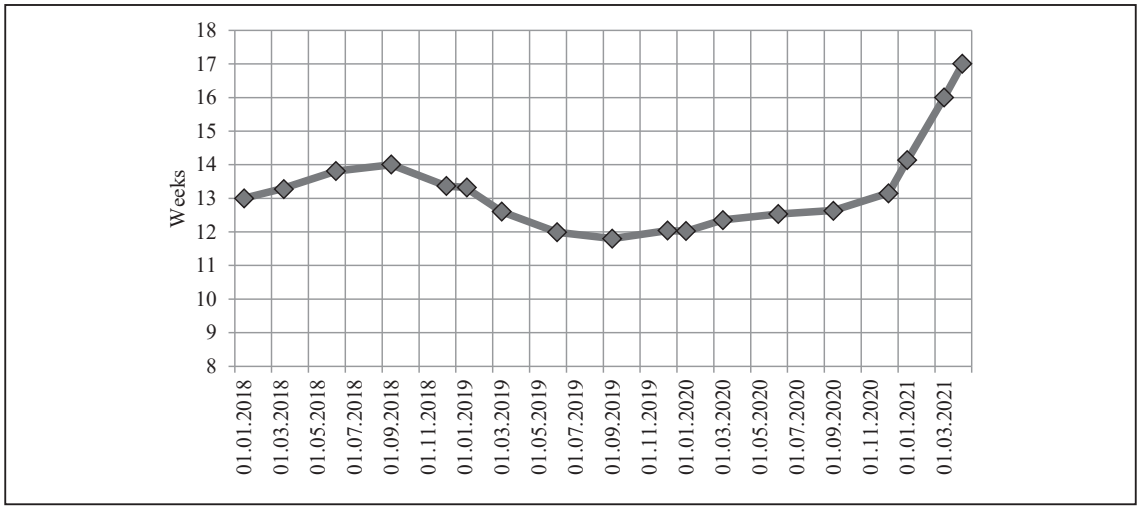
The result of all the unfavorable trends was that the global demand for microcircuits, as TrendForce analysts found out, turned out to be 10–30% higher than the current supply.

An increase in demand led to an increase in prices. From autumn 2020 to spring 2021, TMSC and other Taiwanese semiconductor companies raised chip prices by 10%. But, since demand for chips continued to exceed supply over time, TMSC, fearing a decrease in capitalization and profitability, increased the cost of chips by another 20% at the end of August 2021. At the same time, South Korean



Source: https://www.tadviser.ru/index.php/Статья:Полупроводники

Fig. 1. Production of personal computers (including laptops and mobile workstations) in the world in 2014–2021



Source: https://3dnews.ru/1039914/sroki-ogidaniya-zakazov-v-poluprovodnikovoy-otrasli-rastut-chetvyortiy-mesyats-podryad

Fig. 2. Dynamics of chip waiting time in 2018–2021

Samsung and Key Foundry raised prices for contract manufacturing of chips by 15-20%.

One of the hardest hit markets from the microchip shortage has been the automotive market. Prior to the shortage and subsequent rise in the cost of chips, the car market was severely affected by the pandemic and rising energy prices. The lack of chips caused the greatest damage to the car market because the automotive industry has always received

the microelectronics necessary to assemble a car according to the “leftover” principle, since semiconductor manufacturers have a priority in the production of microchips for mobile phones and computer equipment [2]. For example, at the end of 2020, Apple bought 80% of its production capacity from TSMC, which means that it will prioritize the production of semiconductors specifically for Apple technology.

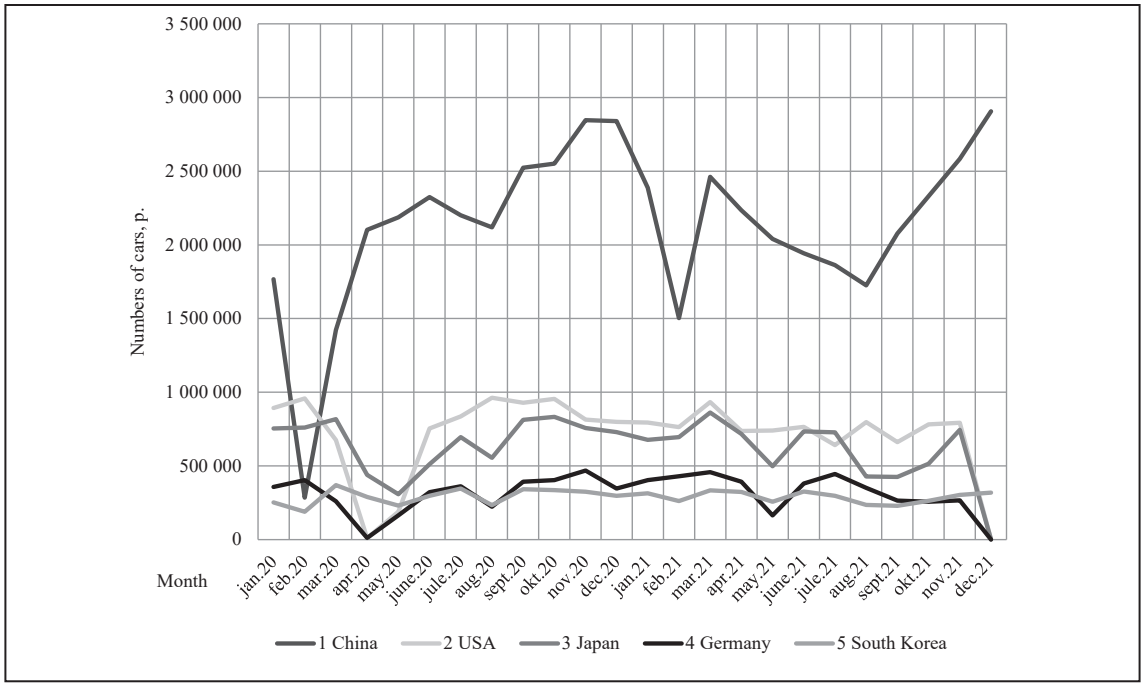
Note that from an economic point of view, the demand for microchips for consumer electronics is in direct competition with the demand for automotive microchips. Microchip manufacturers prefer to primarily manufacture and supply microchips for consumer electronics because they are more profitable and their production technology is easier to use.

In addition, automakers often did not build up significant inventories of components in order to prevent capital idling in the highly competitive automotive market.

Rising costs and expectations for chips have led to a shortage of chips and parts for cars. This either significantly slows down the production of one unit, or limits the number of options in the car, or completely stops the pipeline. In 2021, Audi and Toyota have cut production by 40–60%, and Ford, Fiat, Chrysler, Nissan, Suzuki and Volkswagen have been hit hard. In November 2021, AvtoVAZ completely stopped the conveyor of car assembly lines. The company also stopped installing multimedia systems due to a lack of chips for them.

So, figure 3 shows the dynamics of the number of cars produced for 2020–2021 by months in the leading countries of the world auto production.

The graph shows a significant decline in production in the US, Japan, Germany and South Korea at the beginning of the pandemic from March 2020 to June 2020. In China, growth in new car production slowed down during this period. The story of a sharp decline



Source: https://auto.vercity.ru/statistics/production/

Fig. 3. Number of cars produced in 2020–2021 by month

repeated in May 2021 – here the reason was just failures in the supply of electronics.

As a result, global automakers are losing a significant portion of their profits. Thus, according to the consulting company Alixparthners, the global auto industry lost about 2 billion dollars in revenue in 2021.

Due to the forced reduction and slowdown in production, the released models are rapidly growing in price, which is shown in figure 4. Thus, according to the analytical agency "AVTOSTAT", the weighted average price of a passenger car in Russia in 2021 increased by 23% compared to 2020 and amounted to 2070000 rubles.

Mining plays a key role in the current shortage. Mining (from the English mining – to mine) is the activity of creating new structures to ensure the functioning of cryptocurrency platforms. Virtual currencies (virtual currencies, also known as cryptocurrencies) are a type of virtual assets based on strong cryptography and networking algorithms [7]. A distinctive feature of virtual currencies is their lack of intrinsic value (intrinsic value). Cryptocurrency accounting units are abstract, they exist only as part of specialized software. The network effect plays an important role in shaping the value of cryptocurrencies: the more participants in the system, the more useful and valuable it is (by analogy with the telephone and the Internet) [9].

Cryptocurrency mining is directly related to solving problems of varying complexity with the help of electronic computers, therefore, at present, mining is closely connected with the electronics market, namely with the markets for processors and video adapters. Initially, ordinary user computers were enough for the mining process, but as the network grew, their capacities became insufficient. In this regard, mining "farms" began to be used – video cards that form a set of computer equipment [6].

The main equipment on which mining is carried out are the processors of such large companies as Intel and AMD, and video cards, which are produced by the same AMD and NVIDIA.

Interest in mining over the past 5 years has significantly increased the demand for powerful graphics cards. Video cards in 2021 were sold at a markup of two, three, and sometimes four times.

Thus, an increase in demand for mining leads to an increase in demand for video cards,

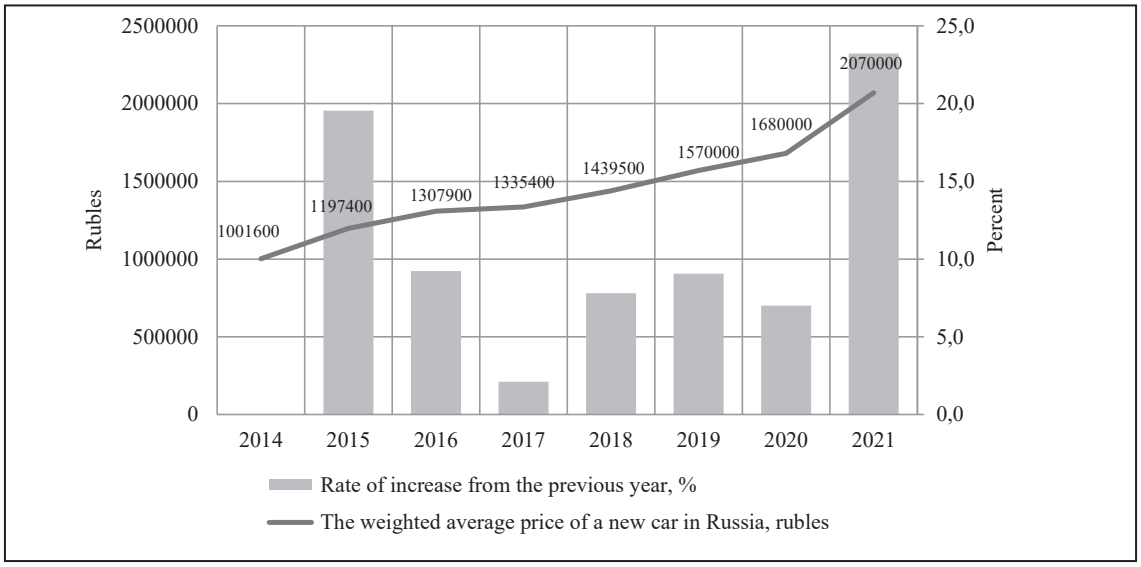


Fig. 4. Dynamics of price changes for a new passenger car in Russia in 2014–2021

which, accordingly, increases the demand for semiconductors that are their components. As a result, the mining "boom" has become not the only, but a significant factor in the shortage of microchips. Therefore, it seems important for the study to conduct a correlation-regression analysis between video cards, as devices that use a large share of semiconductor products, and Bitcoin, the demand for mining of which has become a private cause of the shortage in the microchip market.

Correlation-regression analysis of the time series of the cost of Bitcoin and popular video card models in 2021

In order to evaluate the impact of the Bitcoin exchange rate on the cost of video cards in quantitative terms, we will conduct a correlation-regression analysis of the dynamic series of the cost of Bitcoin and popular video card models in 2021.

Thus, the analytical agency 3DCenter constantly updates information on the cost of the latter. In particular, the prices of almost all graphics cards have risen, while their availability has declined. Note that an astonishing number of (relatively) graphics cards have sold out at reasonable offers, while new models have only hit the market at high or absurdly high price ranges. This has led to skyrocketing prices for popular card models such as the Radeon RX 6800 and 6800 XT, Radeon RX 6900 XT, GeForce RTX 3070 Ti, as well as a new price record for the GeForce RTX 3090.

The initial data on the cost of the listed video cards in the context of 3DCenter dynamic monitoring, as well as the Bitcoin exchange rate in the same time period, are presented in table 2.

Table 2. Initial data for the study, dollars

Date	Bitcoin	Video card models				
	BTC	6800	6800XT	6900XT	3070	3090
17 January	36010.27	1104.112	1327.592	1866.36	1098.072	2449.22
22 January	33655.72	1172.8024	1397.8734	1804.8261	1051.142	2571.8924
2 February	35660.29	1150.4286	1433.8151	1841.4093	1234.842	2803.1146
14 February	48928.54	1489.548	1531.968	1859.208	1362.288	3055.452
24 February	48762.63	1334.6256	1516.1784	2109.4128	1547.146	3726.9936
18 March	57780.26	1424.5409	1676.1419	2072.114	1795.952	3818.3447
19 April	56253.42	1843.2603	1882.1856	2503.7919	1789.963	3442.1898
2 May	56829.29	1848.4224	2048.7885	2603.5559	1785.846	3633.0646
16 May	44162.96	1942.3053	1881.5703	2853.3303	1911.33	3885.8253
30 May	36091.85	1639.8144	1713.0204	2744.0049	1780.126	3781.0899
20 June	35808.84	1793.5225	1990.3653	2720.2252	1415.845	3260.3571
4 July	35526.5	1630.251	1535.331	2266.215	1357.949	2975.742
18 July	31701.86	1325.082	1451.449	2023.053	1280.795	2623.001
8 August	43786.38	1380.9762	1606.8258	2246.733	1222.764	2993.0954
29 August	48878.9	1754.655	1726.3446	1980.5484	1485.116	3216.1794
19 September	47604.84	1699.9668	1905.8634	2001.4792	1460.047	3578.8466
10 October	55433.79	1705.2706	1728.9871	1983.5051	1564.707	3365.4221
31 October	61005.07	1853.9032	1756.2381	2015.7152	1642.392	3888.1112

Source: https://www.3dcenter.org/news/hardware-und-nachrichten-links-des-3031-oktober-2021

Let's build a matrix of pairwise correlation coefficients for the Bitcoin exchange rate and the cost of video cards – a table in which the correlation coefficient is located at the intersection of the corresponding row and column. This procedure is necessary to identify the relationship between the indicated factors.

MS Excel uses the Correlation procedure to calculate correlation matrices.

The correlation matrix is presented in table 3.

The correlation matrix allows us to draw the following conclusions:

• the correlation between the indicators is moderate, R2 ranges from 0.51 to 0.67, with the exception of the 6900XT model, the price dynamics of which does not depend on the current situation in the cryptocurrency market;

• to the greatest extent, the relationship between the Bitcoin exchange rate and the cost of video cards can be traced for the GeForce RTX 3090 model, we note that this model is represented by the highest price range and powerful technical characteristics, which makes it in demand for "miners" (fig. 5).

Thus, the revealed relationship between the dynamics of the Bitcoin exchange rate and the cost of the GeForce RTX 3090 video card is of interest for further research. In order to determine the degree of influence of the Bitcoin exchange rate on the price of this video card model, let's look at a paired linear regression of these indicators. The model that estimates the dependence of the cost of a video card on the Bitcoin rate is presented in table 4.

We note the significance of the constant, since the P-value of the Y-intercept is less than 0.05, therefore, there is no need to re-evaluate the equation. The pairwise correlation coefficient, equal to 0.6712, indicates a moderate degree of correlation between the cost of a video card and the dynamics of the Bitcoin exchange rate. Judging by the value of the coefficient of determination, the price variation for GeForce RTX 3090 video cards in 2021 is only 45.1% due to the variation in the Bitcoin exchange rate. Fisher's F-test and Student's t-test for BTC, i.e. the factor trait, are significant, hence the model as a whole is statistically significant.

According to the results of the constructed paired linear regression model, the tightness of the relationship between the price of video cards and the bitcoin rate was 67%. This indicates a direct and close relationship between the bitcoin rate and the cost of the GeForce RTX 3090 video card. But this relationship cannot be called decisive. The appreciation of bitcoin, first of all, encourages miners to expand and improve their power by purchasing more powerful video cards. Accordingly, manufacturers raise prices due to increased demand. Here, a clearly identified connection can be traced.

The situation with the depreciation of bitcoin is more difficult. The collapse in the price of cryptocurrency is forcing miners to quickly sell equipment, fearing the loss of capital. Used graphics cards saturate the secondary market, resulting in oversupply. This becomes one of the factors that force

Table 3. Correlation matrix of the Bitcoin exchange rate and the cost of popular video card models

	BTC	*6800*	*6800XT*	*6900XT*	*3070*	*3090*
BTC	1					
6800	**0.520771**	1				
6800XT	**0.511243**	0.887724	1			
6900XT	**0.011614**	0.647844	0.689042	1		
3070	**0.630483**	0.749532	0.717976	0.651797	1	
3090	**0.671228**	0.698746	0.698799	0.527544	0.904525	1

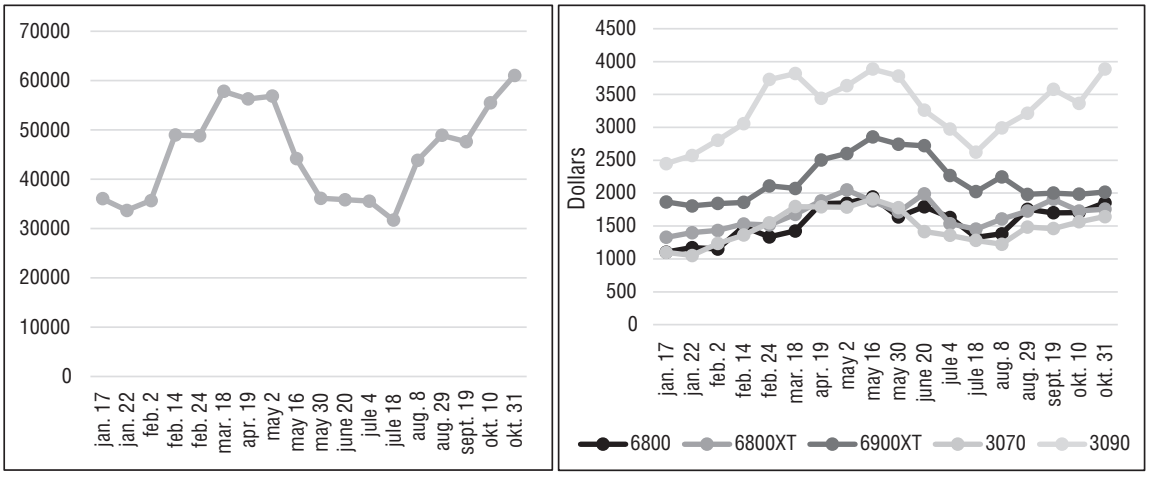


Fig. 5. Dynamics of the Bitcoin exchange rate and the cost of popular video card models

Table 4. Model of paired linear regression of the impact of the Bitcoin exchange rate on the cost of the GeForce GTX 3090 graphics card in 2021

Regression statistics						
Multiple R			0.671227569			
R-square			0.45054645			
Normalized R-squared			0.416205603			
Standard error			361.5026928			
Observations			18			
Analysis of variance						
Indicator	df	SS	MS	F	Significance F	
Regression	1	1714555.878	1714555.9	13.11984095	0.002289617	
Remainder	16	2090947.15	130684.2			
Total	17	3805503.028				
Indicator	Coefficients	Standard error	t-statistic	P-value	Lower 95%	Upper 95%
Y-intersection	1789.6345	420.6104	4.2549	0.000605	897.9802	2681.289
BTC	0.0330	0.0091	3.6221	0.002290	0.0137	0.0523

manufacturers to restrain and sometimes reduce prices for new video cards. But do not forget that the demand for video cards is not limited to miners. Powerful video cards are essential for gamers, animation creators, graphic designers, big data processing specialists. Therefore, changing trends in these areas also affect demand, and, accordingly, the price of video cards.

It should also be noted that the cryptocurrency does not have a material embodiment and is presented only in digital form [8], so the depreciation of bitcoin cannot devalue a video card. A complex, expensive technology of creation, innovative components produced by a limited number of companies, forms a high-cost price of a video card, the price of which will always exceed it.

As a result, the existence of a connection between the bitcoin rate and the price of a video card is undeniable, but it cannot be called a determining one. In the constructed model, the video card model most often used in mining showed the greatest closeness of connection, the other analyzed models showed lower values. But the use of video cards is not limited to cryptocurrency mining, their use extends to all areas where a computer is used. Therefore, despite popular belief, the bitcoin rate does not have a key impact on the cost of video cards.

According to the results of the model we built, more than 33% of the influence on the price of video cards have other factors, that is, not the bitcoin rate. Including, as we have already found out, it is precisely the shortage of semiconductors that is a non-permanent factor.

One of the factors affecting the price of a video card, for example, may be the increase in copper prices. The basis of all electronic products is copper foil – Copper Coated Laminates (CCL). Prices per ton of copper for the period from January 2020 to December 2021 rose by more than 50% (from 6176.27 to 9509.4 dollars), as shown in figure 6.

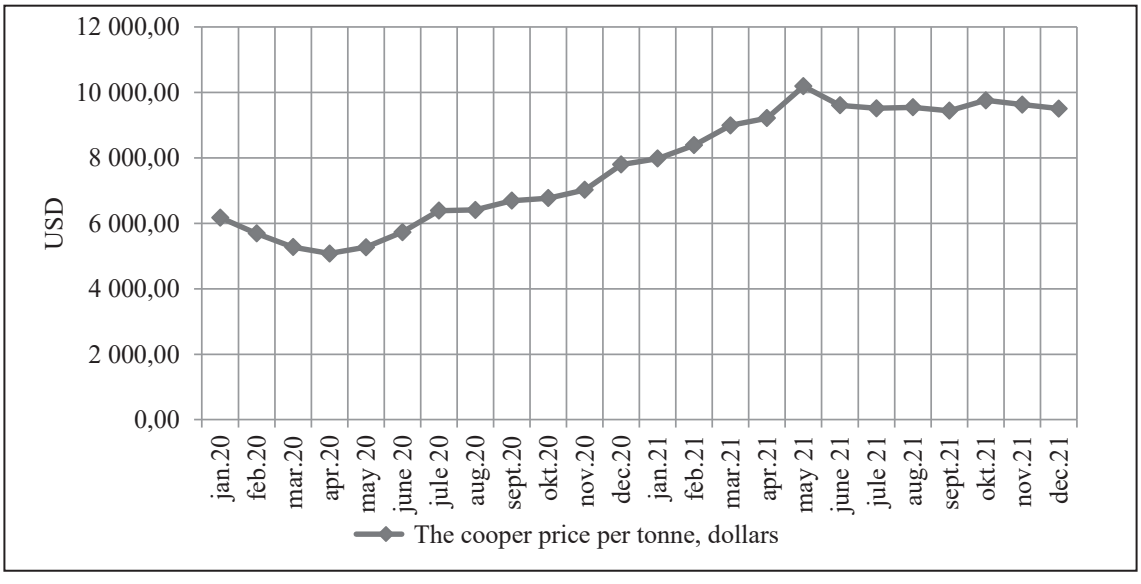
Throughout the period presented, the price of copper continued to rise. News outlets report that, combined with increased shipping costs, the price tag of copper foil has increased by 35%.

Thus, the prices for video cards depend on many factors, which is determined by the complexity of its production, extensive scope, as well as expensive components.

The state of the semiconductor industry in a period of scarcity

Currently, microchip manufacturers, despite a serious crisis, remain in a big plus, as demand continues to grow, and in the end, the buyer pays all costs. Figure 7 shows the dynamics of changes in the received profit in the first quarters of 2020 and 2021.

Most of the world's chip manufacturers have increased their profits. Semiconductor industry leader TMSC posted a net profit of 6 billion



Source: https://bhom.ru/commodities/med/?startdate=3years

Fig. 6. Average dynamics of copper prices by months 2020–2021

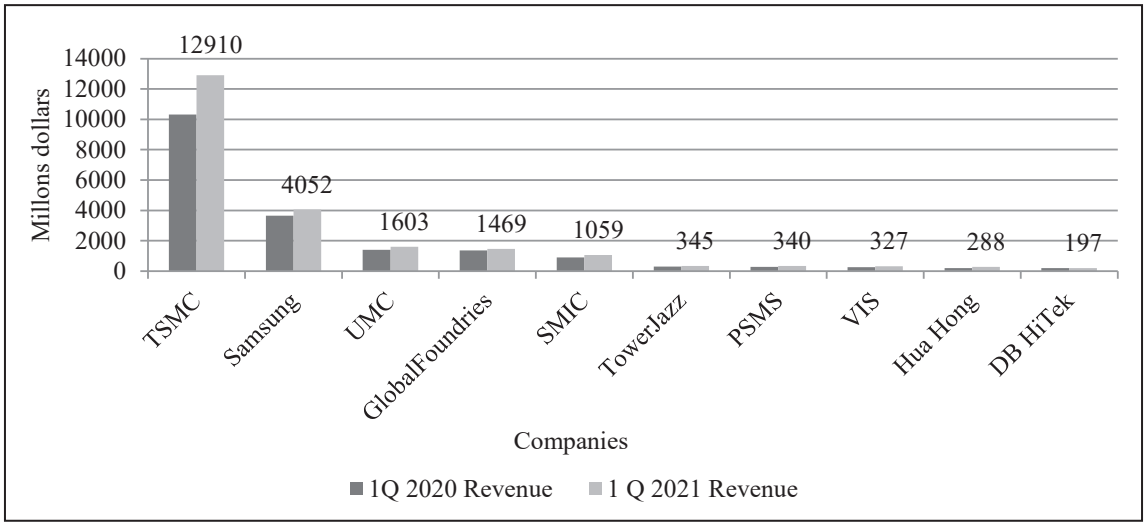
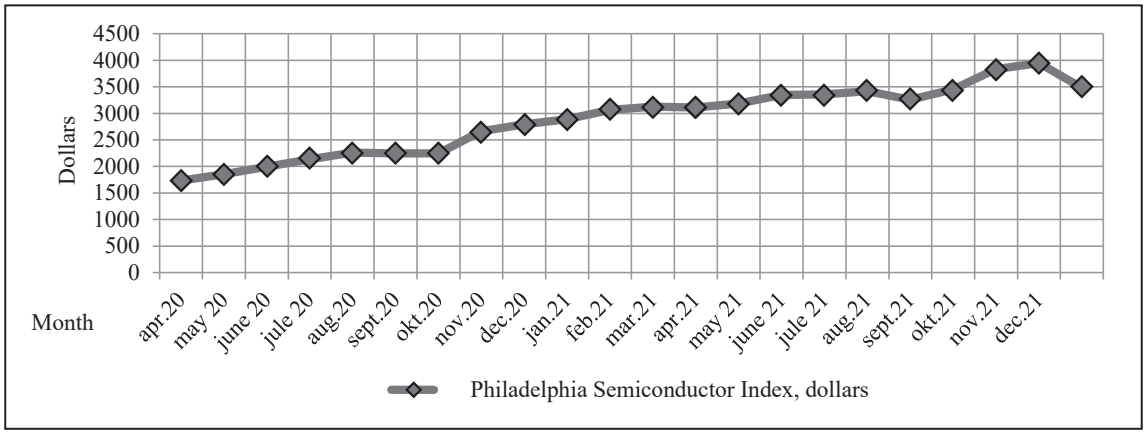


Fig. 7. Revenues of global semiconductor manufacturers in the first quarters of 2020–2021

dollars in October-December 2021, up 16.4% from a year ago. TSMC's quarterly revenue rose 21.2% year-on-year, also a high. Gross margin was 52.7% versus 51.3% in the previous trimester. TSMC's annual results also turned out to be unprecedented: the company's turnover grew by 18.5%, to 58 billion, and net profit increased by 15.2%, to 21.6 billion dollars.

Shares of the semiconductor industry from the beginning of 2020 to the end of 2021 showed stable growth, the PHLX stock index in 2021 updated its historical high. Figure 8 shows the index changes.

Thus, the lack of semiconductors is not a fundamental and disruptive problem for microchip manufacturing companies. Firstly, the resulting deficit was offset by rising prices, which allowed key players to significantly increase profits. Second, the semiconductor crisis is creating pent-up demand that will be realized over the next few quarters as production recovers.



Source: https://ru.investing.com/indices/phlx-semiconductor

Fig. 8. Dynamics of the semiconductor industry stock index

Conclusion

Microchips have long been the basis of most electronic devices: from a smartphone to a climate control system in a car. Therefore, in the context of global digitalization, semiconductors are becoming an inconspicuous, but absolutely indispensable part of almost all sectors of the economy.

The semiconductor industry market is one of the fastest growing and lucrative markets. Therefore, despite the clear leader – TSMC, the closest competitors are increasing their investments in the construction of new production facilities, the development of unique technologies to expand their market share. The semiconductor manufacturing industry has become strategically important for technology leaders – competition between the US and China in the electronics industry has reached its limit. The competitive war resulted in American sanctions against Chinese companies, which, in turn, began to accelerate the transition from borrowed innovations to the development of their own technologies, which in the near future will only increase competition in the market for components for modern electronics.

The shortage of microchips was caused by several reasons that link large sectors of the modern economy, such as the electronics market and the automotive industry. The coronavirus pandemic, intensifying competition in the semiconductor manufacturing market for electronics, the rapid development of the popularity of cryptocurrency mining, natural disasters have created a chain of events that have led to supply chain disruption, production downtime, and sometimes its complete closure.

The novelty of the author's research lies in determining the relationship between various factors that influence the development trends of the electronics market. As an assessment of the impact of the shortage of semiconductors on the final cost of electronics, the dynamics of prices for video cards, which are increasing due to the popularity of cryptocurrency mining, was used. Contrary to the established opinion of experts, the study showed that changes in the cryptocurrency exchange rate (using the example of Bitcoin) are not the determining factor in the formation of the price of video cards (microelectronics).

In the course of the study, it was determined that the shortage of semiconductors is a variable factor affecting the prices of video cards, the final price of electronics, car components, etc.

Thus, the shortage of microchips is a global problem, the solution of which the world semiconductor industry is currently unable to offer. However, after analyzing the income of key players in the microchip market during the period of shortage, we can conclude that the semiconductor crisis has become a development driver for manufacturers.

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