CZECH UNIVERSITY OF LIFE SCIENCES PRAGUE

Faculty of Economics and Management

Department of Economics

Bachelor Thesis

INFLUENCE OF GOLD PRICE UPON ENVIRONMENTAL QUALITY

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BACHELOR THESIS ASSIGNMENT

Barbora Pištorová

Economics and Management

Thesis title

Influence of Gold Price upon Environmetnal Quality

Objectives of thesis

Identify relationship between air mercury pollution and production of gold. Quantify relationship between gold production and price of gold. Predict future price of gold and its determinants. Evaluate use of environmentally friendly technologies in gold mining.

Methodology

Literature review will be conducted using methods of synthesis, induction, deduction and extraction. Analytical section will be done using methods of both qualitative (descriptive) as well as quantitative such as regression analysis.

The proposed extent of the thesis

35 pages

Keywords

Gold mining, mercury pollution, price of gold

Recommended information sources

EDGAR – Emission Database for Global Atmospheric Research (2008) Emission Inventory – Hg Gridmaps 0.1degx0.1deg from 1970 to 2008 (yearly files) by sector, Gold _ A and Gold _ L, [Online], Available: http://edgar.jrc.e [19 Dec 2014]

Hentschel, T., Hruschka, F. and Priester, M. (2003) Artisanal and Small-scale Mining: Challenges and Opportunities, Nottingham: Russel Press Ltd., ISBN 1843694700

Kirkpatrick, Ch. and Dahlquist, J. (2011) Technical Analysis: The Complete Resource for Financial Market Technicians, 2 nd ed. New Jersey: Pearson Education, Inc., ISBN-13: 978-0-13-705944-7

Telmer, K. and Stapper, D. (2012) A Practical Guide: Reducing Mercury Use in Artisanal and Small-scale Gold Mining, Geneva, ISBN 978-92-807-3282-5

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DECLARATION

I declare that I have worked on my bachelor thesis “Influence of Price Gold upon Environmental Quality” by myself and I have used only the sources mentioned at the end of the thesis. As the author of the bachelor thesis, I declare that the thesis does not break copyrights of any third person.

In Prague ....

Barbora Pištorová

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PREFACE

This thesis was submitted and presented at international conference organized by Euroleague for Life Sciences - Scientific Student Conference Warsaw 2014.

Influence of Price Gold upon Environmental Quality

Vliv ceny zlata na životní prostředí

Summary

This bachelor thesis examines whether the price of gold can affect environmental quality. In the first part is a literature review as an introduction to the issue of air pollution associated with gold mining using mercury. The second chapter is the analytical part, which is further divided into several sections. Crucial part of this thesis is in the first subchapter, where the author was ascertained by using regression analysis, whether there is any relationship between the variables of air mercury pollution in relation to artisanal and small scale and large scale gold mining and gold production. Another regression framework demonstrates the dependence between gold production and the price of gold. It continues with technical analysis to predict the gold price with the help of moving averages. The last part of the analytical chapter proposed various solutions to reduce mercury pollution from gold mining. The aim of the thesis is to determine whether the price of gold may negatively affects the quality of the environment and suggests possible solutions.

Souhrn

Tato bakalářská práce zkoumá, zda cena zlata může ovlivňovat kvalitu životního prostředí. V první části je literární rešerše jako úvod do dané problematiky týkající se znečistění ovzduší při těžbě zlata za pomocí rtuti. Druhou kapitolou je analytická část, která se dále rozděluje na několik sekcí. Stěžejní část této práce se nachází hned v první podkapitole, kde autor zjišťuje s využitím regresní analýzy, zda existuje nějaký vztah mezi proměnnými znečištění ovzduší rtutí v souvislosti s malým řemeslným a velkým měřítkem v těžbě zlata se samotnou těžbou zlata. Další regresní rámec dokazuje závislost mezi těžbou a cenou zlata. Navazuje technická analýza s cílem předpovědět cenu zlata za pomoci pohyblivých průměrů. Poslední část analytické kapitoly navrhuje různá řešení na snížení znečistění rtuti z těžby zlata. Cílem této bakalářské práce je zjistit, zda cena zlata může negativně ovlivňovat kvalitu životního prostředí a navrhnout případná řešení.

Key words: gold production, mercury pollution, price of gold, artisanal and small scale gold mining (ASGM)

Klíčová slova: těžba zlata, znečištění rtutí, cena zlata, řemeslná těžba zlata v malém rozsahu

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List of Abbreviations

ASGM	Artisanal and Small Scale Gold Mining
Au	gold
EDGAR	Emission Database for Global Atmospheric Research
EMA	Exponential Moving Average
G	gram
GMOS	Global Mercury Observation System
Hg	mercury
i.e.	*id est.*, that is
Kg	kilogram
LS	Large Scale Gold Mining
MA	Moving Average
Oz	ounce
SMA	Simple Moving Average
t	tonne
U.S.	The United States
USD	United States Dollar
UNEP	United Nations Environment Programme
VAT	Value Added Tax

1. INTORDUCTION

Gold production is responsible for environmental degradation in many parts of the world. Due to damaging methods of gold extraction used mainly by artisanal and small scale gold miners, water, soil, and air are negatively affected by mercury pollution. One fourth of supply of gold comes from artisanal and small scale gold mining (ASGM), which leads to release approximately 1000 tonnes of toxic mercury per year (Fuller, 2014). Given overall scarcity of gold and decreasing gold deposits, it is clear that gold mining cannot be expected to stop.

Gold production has several stages that are most important for potential environmental hazard related to mercury. In a reduction strategy of mercury there is very important the concentration stage. The least materials is needed to process through a separation method, the better is the concentration. The concentration stage has an environmentally friendly, yet relatively more expensive option of shaking tables that work based on gravity or flotation. In this research are evaluated possible scenarios for more environmentally friendly technology incorporation.

Also, as part of the bachelor thesis, influence of global gold price upon profitability in the industry and its related environmental effects are studied. While, in general, higher price will lead to higher environmental degradation due to increasing number of gold mines, it is also true that low price of gold may push gold producers to less environmentally friendly mining techniques. As the price of gold is approaching the cost of production at around $1150 per ounce (Schnider, 2013), worries about environmental threats becomes more imminent.

2. OBJECTIVES AND METHODOLOGY

2.1. Objectives

Name of this bachelor thesis Influence of Gold Price upon Environmental Quality reveals one of the main objectives, which are to identify relationships between air mercury pollution and production of gold and also quantify relationship between gold production and price of gold, using the regression analysis. Another aim of thesis is focused on technical analysis of gold price through the tools of Simple and Exponential Moving Averages. Last chapter of analytical part is to evaluate use of environmentally friendly technologies in gold mining. It is focused on improving techniques for artisanal and small scale gold mining and government based possible solutions.

2.2. Methodology

For composition of this thesis were used several methods. Firstly the literature review was written by the artist as an introduction to the issues related to the importance, history, and the use of gold as well as its price and mining in relation to air mercury pollution. For the part of literature review were used methods of induction, deduction, extraction and synthesis from specialized literature, abstracts, articles and other electronic sources.

Data for chapter of analysis were collected and compiled from different sources. Data of air mercury pollution were adapted to sector of artisanal and small scale gold mining and also for large scale sector. These data were collected from EDGAR - Emission Database for Global Atmospheric Research, where the author get an access from Dr. Sergio Cinnirella, the Cyber(e)-infrastructure Responsible in GMOS (Global Mercury Observation System) via e-mail conversation. Raw data were received in .txt format, than transformed and processed by using Microsoft Office Excel 2007. Time period was 39 years of observation from 1970 until 2008. There were various amounts of samples, between 32,250 to 55,034 samples per year. Therefore data were processed as an average for each year. Other data for gold price and production of gold were gathered from different statistical databases available on the Internet, than processed again with the use of Microsoft Office Excel 2007. The resulting tables of regression framework of relationship between gold price, production of gold and related mercury pollution were calculated by Gretl version 9.1.13 win32.

Technical analysis of gold price and its future prediction with application tools of moving averages were processed by using Advinion Professional Chart available on Investing.com.

3. THEORETICAL PART

3.1. Literature review

Chapter of literature review deals with the topic of production and the price of gold in relation to air mercury pollution. Especially very extensive and s persistent problem with air mercury pollution is in connection with ASGM sector of gold production. Multiple studies in this area have been conducted.

Fuller (2014), in an interview with the Blacksmith Institute explains the importance of gold mining by ASGM, that not all the gold is mined by large scale mining companies. He estimated that about one fourth of the world´s supply of gold comes from small scale mines. Telmer and Stapper (2012) in their work specify that in 2011 the highest demand for mercury formed ASGM sector with a total of 24% roughly equivalent to 1,400 tonnes of mercury consumed by small scale miners globally. Research by the United Nations Environmental Program (UNEP) for mercury pollution from anthropogenic sources states coincides with the previous statement by Telmer and Stapper. In UNEP Global Mercury Assessment (2013) is stated with the help of highly advanced emission measuring technologies that air anthropogenic mercury emission to air in 2010 indicates, that 727 tonnes comes from ASGM and 97.3 tonnes from large-scale gold production.

Nriagu (1994) in his article states that mercury is a serious problem because it mined more and more gold. Between years 1580 - 1900 90% of the mercury used in the US was for the purpose of gold mining. With a very important idea opposes Baur (2014) in his study. It comes with the fact that gold mining increases with rising gold price and falls with the negative changes in the price of gold. Nevertheless, according to Schnider (2013) low marginal cost of gold mining is explained by the cost of production in 2013 is estimated to be 1150 USD/oz and the price of gold in 2013 falls to 1204 USD/oz. At the same time gold production increased in comparison to previous years.

However, Fuller (2014) adds that gold mining now and throughout the world is increasingly stronger and stronger. In addition, he points out that, due to the steady increase in gold prices over the last decade, more people from the area of ASGM are

drawn into hazardous gold mining techniques using toxic mercury and thus is released more mercury into the air.

Many international environmental organization deals with problems related to the release of toxic mercury in gold mining, depending on whether in large or small scale. Unfortunately, data on that kind of pollution are not usually open to the public. Based on the analysis of the literature is not entirely clear whether it is the relationship between the three basic elements namely gold price, production of gold and mercury pollution.

3.2. Gold in General

Gold, Latin called as aurum and with the symbol Au, is an precious chemical element. Because of the high economic value belong into the group of precious metal with silver and platinum. Gold is very heavy metal, its specific weight is 19.3 g/cm^3. It means that 1 kilogram of gold can be cast into cube with 3.75 cm per side. Gold is known for its incompatibility and resistance against acids, alkalines, salts. Also external influences barely affect it. The only think which dissolved the *king of metals* (Rex Metallorum – the nickname used by ancient alchemists) is aqua regia, which is mixture of hydrochloric and nitric acid, or similar mixtures of acids and cyanide solutions.

On the other hand gold has relatively low melting point 1063 degree of Celsius, therefore it can be easily processed. It is perfectly ductile and malleable. From only 31,103481 grams of gold, is possible to pull out 80 kilometres of wire. Gold is very soft material destroyable only by nail, so even its processing can be by cold. Nowadays gold is primarily used for this feature in alloys with other metals. It gains needed hardness, but also it influences its colour. For example copper dyes gold to red or yellow, cadmium to green and with adding nickel or palladium is formed white gold (Pleskotová, 1983: 10-11).

Occurrence of Gold

It can be said that right answer for the question *where the gold is found* is everywhere. Gold is practically everywhere around the world just is trace elements. There is not any other substance that extended. It is in the air, water, ground; it is collected by roots of plants as well as bodies of animals or people. Only tiny part of whole gold amount is contained in ground into deposit, where is possible to mine gold. One tonne of the Earth´s

crust contains 5 milligrams of gold. In sea water the proportion is 0.03 – 0.44 milligrams of gold per one cubic meter.

As was mentioned before gold is not chemically inert so in the nature is frequently occurred as pure metal or with just a little additive of silver, copper, platinum, lead, mercury or bismuth. Usually is found in form of grain or scale in quartz veins pervading various rocks. Exceptionally are found bigger stones of gold, with the weight of several kilograms, termed nuggets. The biggest one was found in Australia in 1869 called Welcome Stranger, weighting 64.269 kilograms. Relatively often nuggets are found in Siberian deposits (Pleskotová, 1983: 11-12).

3.2.1. History of Gold Mining

In these paragraphs is brief summary through the history of gold in consonance with The New Encyclopaedia Britannica (2003: 336-337). Main sources of metal for ancient Egypt and Mesopotamia were alluvial gold deposits found around or directly in streams. Other deposits were found in today's Turkey, Iran, Persia, China, India and other countries. In the time of middle age the mines of Saxony and Austria were major sources of gold in Europe. The greatest era of gold production occurred after Spanish discovery of the America in the 1940s. Thanks to exploiting slave labour in mines and looting Indian temples, tombs and palaces in Central and South America was a huge influx of gold to Europe, thereby put its economic structure into imbalances. Since Christopher Columbus´ discovery of America in 1942 to 1600, more than 225,000 kg (8,000,000 ounces) of gold, or 35% of world production, came from South America. Mining in Colombia lasted until 17 and 18 century when was minded 80 percent of the total world production amounting to 1,350,000 kg (48 million ounces).

World´s leading production country in 1823 become Russia and turned into important world supplier for 14 years. The period from 1850 to 1875 can be called as the second era of expanding production where production was even more gold than since the 1490s, mainly because of findings in California and Australia. Australian gold rush began in 1851 in regions of Victoria, where prosperous gold deposits were found.

During the third era between 1890 and 1915 was rapid increase of gold production due to gold rushes. Gold rush is defined by rapid increase of fortune seekers to newly discovered gold deposits. Main gold rushes occurred in Alaska, Yukon Territory, and South Africa.

The last great North American gold rushes took place alongside the Klondike and upper Yukon River in Canadian territory in 1896. Another major gold rush was in South Africa which was entirely different from those in Australia and North America. Rich gold deposit was accidentally found by George Harrison from Kimberley while he was searching for diamonds in 1886. After the first year, financers from Kimberley mines started to buying up sections there, and many small mining companies joined up into what became big mining corporations today. They had big advantage, because they could afford more expensive mining equipment and better technologies. This gold rush continued till the end of 20th century, when the South Africa was one of the largest gold producers, counted for one-third of the world´s gold.

Another marked increase in global gold supply came with the introduction of cyanide process for the gold recovery in 1890s. This expansion continued throughout the 20th century, not just because already mentioned raise in South Africa´s gold-mining operations but also because of still improving recovery methods.

Russia, the United States, Australia and also South Africa are four countries that counted together for two-thirds of world gold produced annually in 20th century.

3.3. Applications of Gold

3.3.1. Monetary Exchange

Gold Standard

Gold standard definition according to Investopedia (2014) sounds ´Monetary system in which a country´s government allows its currency unit be freely converted into fixed amounts of gold and vice versa. The exchange rate under the gold standard monetary system is determined by the economic difference for an ounce of gold between two currencies´.

First country which came up with golden standard was Great Britain in 1817 and till 1914 has golden standard 59 countries. Only China never accepted this law. Everybody was satisfied, until the First World War began. In that time the price of gold increase by more than 100% percent. After the war was return to gold standard impossible, simply because

there was not enough of precious metal. Proviso to change money for gold remained only to state, not people anymore. For stabilise an after war currency in a lot of countries were notes covers not only by gold, but also by foreign exchange. From golden coins was established Gold Exchange Standard. But it was not sufficient enough for healing devastate economy from war. Inflation spread and unemployment increased.

It all led to a well know unhappy day – Black Thursday 24. 10. 1926. It was an absolute collapse for world economy. During 1931 almost every European country gave up gold currency, the United States a little later in 1933 and every citizen must hand in gold to state, under threat of strict threat for collecting gold. The United States started with buying of gold abroad, which led to increase of gold price and American president was forced to rearrange ration between gold and US dollar. Dollar was devaluated almost by 41 percent (its golden content decreased from 1.50463 to 0.888671 grams of gold). In a time of general economic crisis was developed only one industry – gold mining, because of increasing of price of gold. Than Hitler came to power and the Second World War began.

In 1945 under the Bretton Woods international monetary agreement of 1944 was established the International Monetary fund, which included more than 130 countries. Main article of Bretton Woods system represented convertibility of American dollar for gold. At the beginning it seemed as great solution for a crisis. But over time gold reserves of the United States began to diminish and in 1965, when France asked for change its dollar deposit for gold, an expected crisis started and capitalistic monetary system disappeared. Value of USD still descended and price of gold ascended.

In international finance is golden meter still really the best, the easiest and the most durable measure of values. Even experts warn against high instability of gold, in international payments is again more and more promote gold. Nowadays no country use gold standard (Pleskotová, 1983: 131-141).

3.3.2. Jewellery

The most popular gold in the world is still the yellow one, but current market offers various palette of gold. Pure 24 carat gold is very malleable. To get more durable gold has a consequence of the process of alloying, which mix pure gold with other metals. By this method can be also change its colour. Very famous colour for gold jewellery is white, pink or even black gold. For example as was mentioned earlier white gold is created by adding

nickel or palladium or cobalt oxide imparts black gold its colour (World Gold Council, 2014).

Troy ounce is a basic unit of measurement gold weight. One troy ounce is equal to 31.1034 grams. It is identical to 20 troy pennyweights. The pennyweight is universal unit of measure in jewellery production, it is equivalent to 1.555 grams of gold (Usagold, 2014). On gold is also measured its purity by ´carats´. This measurement is called ´cartage´. It indicates us how many per cent of gold is in concrete item. Pure gold is 24 carat with no other metals. Every country has own minimum cartage permitted. The most usual is 14 carat gold, but for example in the United States it is 10 carat. In France, the United Kingdom, Portugal and Ireland the legal minimum standard is 9 carat and in Denmark or Greece is the lowest cartage allowed – just 8 carat (World Gold Council, 2014).

Demand for Gold Jewellery

Leading sector of demand for gold has always been jewellery. Gold jewellery is holding the leadership mainly because of its charm, beauty and of course for store of value. In accordance with new dynamics of economic growth and fortune in the world, the world gold demand makes up around 45 per cent.

The two largest markets for gold jewellery come from India and China. In 2012 they perform more than half of international demand. That big demand for gold in these countries has mainly cultural background. Wearing gold jewellery has an important role in case of major festivals and events. There is scanty approach to financial asset has results in gold as enduring store of value. Markets in India and China share essential theory that gold is an investment and an asset which can be passed down through generations.

Due to current still increasing Asian population and continuously improving of life standard in these countries, which should result in the expected growth of disposable income, the demand for gold will retain the current tendency (World Gold Council, 2014).

3.3.3. Technology

Gold has also large application in technology sector.´ Industrial demand for gold continues to be dominated by the electronic sector. Gold´s conductive properties and resistance to corrosion means that it remains central to innovations in wiring and coatings in this field´ (World Gold Council, 2014).

Using gold for an increase on quality of electronic devices is highly spread in manufacture of electronics. As was already mentioned earlier gold has exact properties to helping protect against corrosion and also because of its high reliability it is great conductor. Gold is applied for connectors, switch and relay contacts, soldered joints, connecting wires and connecting strips.

Cell phones, computers, television sets, calculators, global position system units, personal digital assistants and many other electronic appliances. All of these contain very small of gold. Even it is just a bit of global amount of gold, it is important to realise huge quantity and consumption of electronic in current consumer society. Every year is produced around one billion cell phones. Medium life of these devices is estimated nearly two years and they are rarely properly recycled. Though in every device is small volume of gold only, in consequence of massive production of cell phones there is a lot of gold required to be recycled (King, 2014).

3.3.4. Medicine

Also in healthcare industry gold find everyday application. For example in dentistry where is used as alloy with other metal, because pure gold would be so soft. Even if use of gold cost more than other material, it is popular for its outstanding performance such as inert, no allergic and malleable for tiny work of dentist and of course for esthetical appeal. Dentists use gold for filling tooth decays, creating crowns and permanent bridges and orthodontic appliances (King, 2014).

Although gold has been used in dentistry for generations nowadays is also used for treatment of some disease. In certain cancer treatment and other kind of diseases is used the isotope gold-198. Also gold or gold components are used in drugs for the treatment of broad spectrum of diseases (Usagold, 2014).

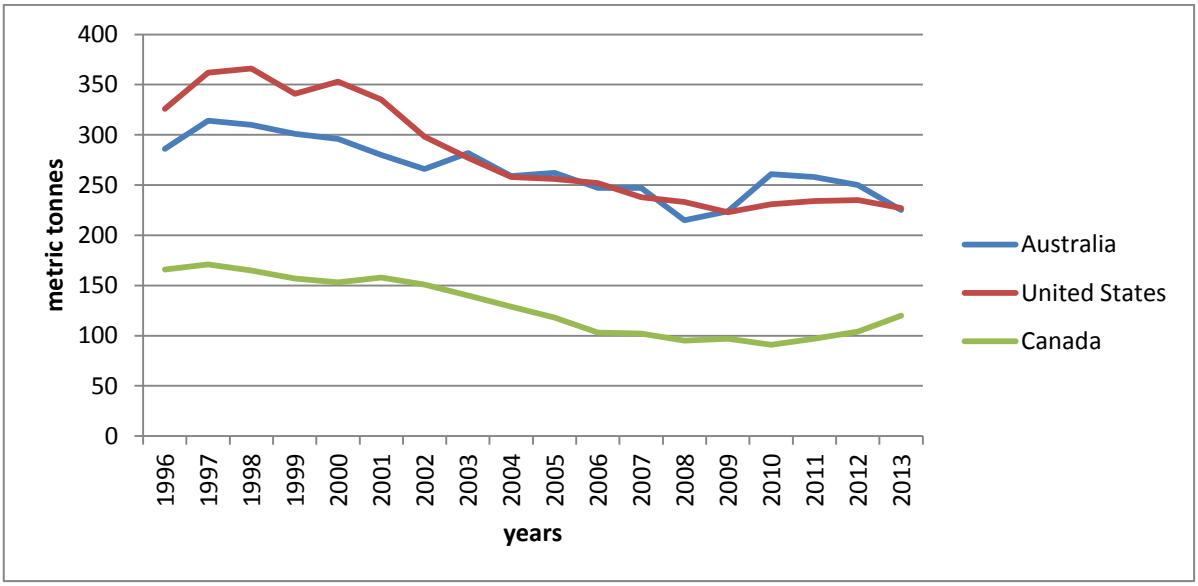
3.3.5. Investment

Another well-known use of gold is for investing into it. Gold can be used as an investment tool, so you can buy so-called investment gold, which is according to European legislation exempted from VAT. Investment gold is a special form of gold, which is used as an investment tool, same as for example securities. These are mainly gold coins and gold bars that are purchased as an investment, i.e. to save paper money (The Gold Investment

(2011). Gold bars also known as gold bullions are specific form of gold, mainly used as secure way of saving financial capital.

3.4. Gold Production Countries

Figure 1: Gold Production (t/year) in Countries with Advanced Economies, 1996-2013



Source: own calculations, data collected from Statista (2014), Index Mundi (2010), USGS (2014), Amey (2000), International Monetary Fund (2014)

Australia

As the second largest gold producing country is Australia considered since 2009, when its amount of produced gold outran the United States. But in 2013 there was a significant decrease of gold produced and the United States were back again before Australia. 75% of Australia´s gold production comes from Western Australia, where is also situated 4,500 tonnes of estimated gold resources. Western Australia´s State Government received royalties 5.14 billion USD from mining. One of biggest mining companies is AngloGold Ashanti Ltd (Gold Fact, 2014 and Statista, 2014).

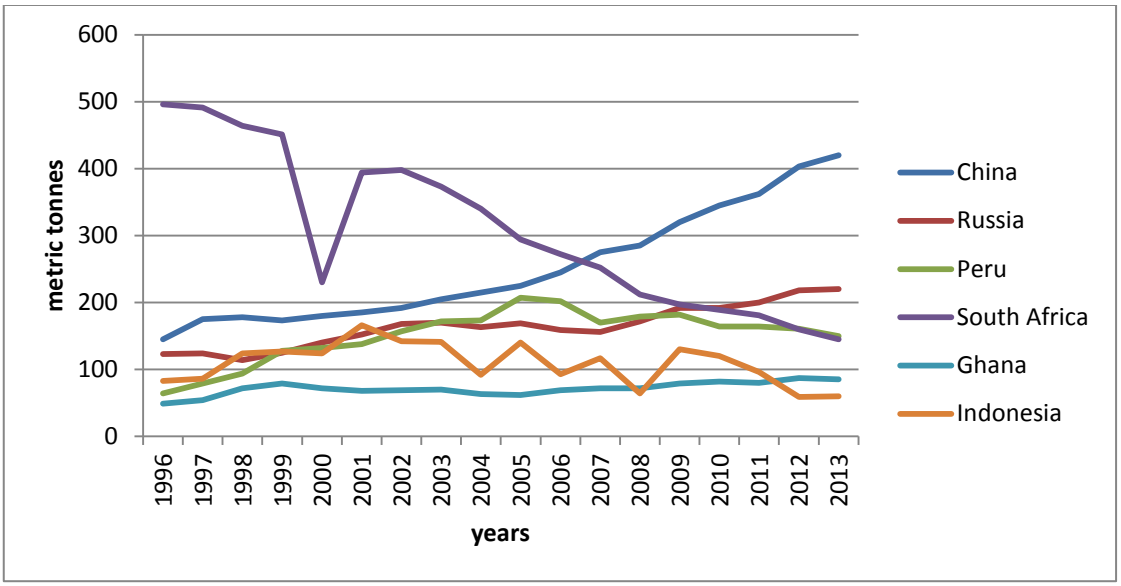
The United States

Another very important state with a large gold production is the United States. In 2013 the US again assumed the role of the second most gold producing country in the world with 227 tonnes of gold mined per year. Gold mining is spread throughout the country but for three-quarters of American gold are responsible only five states: Nevada, Alaska, Colorado, California and South Dakota. 74% of total gold production comes from Nevada, which counted for approximately 10% of state GDP. America holds the biggest sovereign gold reserves, it is reckoned about 26% of the world´s total (Gold Fact, 2014).

Canada

Gold production in Canada occupied since 1997 permanent reduction, but this changed in 2013 when production again rose by nearly 16% compared with the previous year (Gold Fact, 2014).

Figure 2: Gold Production (t/year) in Countries with Emerging Market and Developing Economies, 1996-2013



Source: own calculations, data collected from Statista (2014), Index Mundi (2010), USGS (2014), Amey (2000), International Monetary Fund (2014)

China

Since 2007 China is considered as the largest gold producer in the world with approximately 275 metric tonnes of gold produced per year. From that time its production of gold almost doubled. In 2013 the annual production was counted for 420 metric tonnes. 60% of whole Chinese gold production was mined in five provinces (Henan, Fujian, Jiangxi, Yunnan and Shandong). Although in those provinces occurs predominantly small scale gold mining, China also has a large scale operations. The largest form large scale mining companies is Zijin Mining Company. China is not only leader in gold mining but also represents the country with the largest consumption of gold (Gold Fact, 2014 and Statista, 2014).

Russia

Russia produced 220 tonnes of gold in 2013, it is the largest number in Russian history. Two thirds of its gold production comes from Eastern part of the country from Amur, Khabarovsk, Magadan, Irkutsk, Krasnoyarsk and Sakha-Yakutia. Russia is considered as fourth largest producing country and also as the country with fourth largest gold jewellery market. In 2011 75.1 tonnes of gold were absorbed by Russian jewellery market (Gold Fact, 2014).

Peru

Due to benefits from large scale gold mining Peru is currently the largest producer of gold in South America. Even the numbers still declining since 2002, in 2013 there 150 tonnes of gold minded (Gold Fact, 2014).

South Africa

In the Twentieth Century South Africa was conclusively number one dominating country in entire world´s gold production. It is indicated that South Africa produced about one third of the total gold production, which is counted for some 40,000 tonnes of gold. Nevertheless, already at the end of the 20th century gold mining began rapidly decline. For example, in 1996 was mined 495 tonnes of gold and in 2013 only 160 tonnes. Nowadays there is 35 large scale gold mines, counting TuaTona mine (Gold Fact, 2014).

Ghana

Ghana is considered as the second largest gold producer of African continent and eight largest worldwide. There is located ten large scale companies, the most known are: Newmont (the Ahafo mine), Golden Star Resources (Bogoshu) and Gold Fields (Tarkawa) (Gold Fact, 2014).

Indonesia

There is declining trend in Indonesian trend of gold production for several years. In 2013 in Indonesia were produced around 60 metric tonnes, where almost a half of this amount is represented by huge Grasberg, copper - gold operation in Western Papua. Although it is not significant amount, Grasberg is estimated to hold the largest reserves of gold. There is also a lot of small scale mining (Gold Fact, 2014).

3.5. Gold Mining

3.5.1. Large Scale Gold Mining (LS)

Large scale mining is process usually performed by a large international mining corporation. It involves work of many people with big manual labour force. The company usually mined in a large pre-vetted area and leaves the place, when it is completely dug out.

Large mining companies play an important role in industrial development, mainly in development of technologies. They use still newer and more efficient technologies to reduce costs, increase revenue and mainly to reduce environmental contamination. Especially, in developed countries, mining industry still accepts new innovations to improve the quality of the environment around mining area as well as conditions for workers and interest in landscape restoration at the mine site (Sweeting and Clark, 2000: 2-4).

Although gold mining is highly associated with mercury pollution mainly in ASGM, it is not exclude that toxic mercury can occur in the LS. In various amounts is mercury, as a naturally occurring element, presents in the metal ores. Through the mining and processing these ores, mercury can be released into the air. It may leads to negative impacts on people

and also the environment. But this applies only to mining areas, where the mercury is presented in the ore. In most places it is not presented and cannot be emitted (Mining Facts, 2014).

3.5.2. Artisanal and Small Scale Gold Mining (ASGM)

Hentschel, Hruschka and Priester (2003:5) explain term Artisanal and small scale mining (ASM), 'Broadly speaking, artisanal and small scale mining refers to mining by individuals, groups, families or cooperatives with minimal or no mechanization, often in the informal (illegal) sector of the market. … In some countries a distinction is made between 'artisanal mining' that has some mechanization and is on a larger scale. In some West African countries (for example, Mali), small-scale mining is differentiated from artisanal mining by the presence of permanent, fixed installations that are established one an ore body is confirmed.'

Although ASM is worldwide used term, there is no existing common definition for this expression. There are many regional definitions, which varies by country. The main factors are the macroeconomic situation, geological structures, legal conditions and the history of mining. Anyway, according Hentschel, Hruschka and Priester (2003:6) AMS can be expressed in a variety of conditions:

- Lack of or limited possibilities of use of mechanical devices, and a lot of work that is physically very demanding
- Insufficient qualification of workers
- Occupational safety and health care inadequate
- Low recovery value due to inefficient extraction and processing of minerals
- Use of very small deposits which cannot be used for mechanized mining because it would not be economically exploitable
- Productivity at a low level
- Salaries and incomes at a low level
- Operations are performed in periods either by season or by the development of market price
- Low or even zero level of social security
- Insufficient environmental awareness
- Continual lack of working and investing capital

However, this thesis is focused on Artisanal and small scale gold mining (ASGM) the characteristics of AMS above can be applied also in case of gold mining. ASGM is widely spread in more than 50 developing countries such as Ghana, Brazil, Columbia, Indonesia, Mali and in a lot of other countries.

As Telmer K. and Stapper D. (2012) refers in their work that ´ASGM is a major gold producer and the world´s largest employer in gold mining, representing around 15% of gold supply (around 400 tonnes) and 90% of the gold mining workforce worldwide´.

Methods of ASGM

Method of gold extraction used by so called artisanal and small scale gold miners is very harmful not only to environment but also to human health. In this ASGM method is used toxic mercury. Although use of mercury is in most of countries illegal it is widespread across more than 50 countries. According to Richard Fuller (2014) there are 20 million people around the world who mind gold by using very simple techniques. From this number is estimated to be 4,5 million women and 600 thousand children.

Mercury is used to purify gold from ore in a process of amalgamation. There is a description of steps in Small- scale gold mining described by Fuller (2014) and Schmidt (2012):

1. Miners dig out gold ore from the ground or from rivers
2. If there are some pieces of rocks, they crush into small pieces
3. Broken ore is put into the mills or just into panning bowl with water
4. Add the mercury into it. Mercury sucks up all the tiny pieces of gold and turn into the amalgam (usually mixture of 50% gold and 50% mercury)
5. Take this amalgam, put it into the special bowl and torch to it. The mercury boils off and in the bowl left just gold.
6. But this gold is not perfectly pure, it is called “doré” gold which is a semi-pure alloy of gold. So for the next purification this “doré” gold is sent to refineries.

3.6. Mercury in Gold Mining

As was already mentioned before, mercury is widely used in small scale gold mining. One forth of supply of gold comes from artisanal and small scale gold mining, which leads to release approximately 1000 tonnes of toxic mercury per year (Fuller, 2014).

3.6.1. Why Is Mercury Used?

In consonance with Telmer and Stapper (2012) use of mercury brings several advantages in gold extraction.

- Easy for usage
- The result is known immediately
- For application is one person enough
- Most important benefit is, that use of mercury is cheaper than other substitute methods
- It allows personal decision of how much mercury is used
- It effectively separates gold from sediments in the majority of field conditions
- Lack of information. Miners are unaware of possible threats associated with the use of mercury. Those who are aware usually have no other choice for better alternative, because of the lack of capital.
- The authority instructions, no other choices

3.6.2. Problems with Mercury

´Mercury is a powerful neurotoxin that is harmful to people, but especially to developing foetuses, and young children. Once emitted, mercury can travel great distances through the atmosphere, causing global contamination of ecosystems, fish, birds, mammals, and the human food chain. Worldwide, consumption of mercury contaminated seafood puts billions of people at risk of mercury poisoning, with affects brain and nervous system development and function. Local exposures in mining communities that use mercury can be even more acute´ (Telmer and Stapper, 2012:8).

Health Risks to ASGM Miners

Between one of the big topics of toxic mercury is its negative impact on human health. In connection with artisanal and small scale gold mining, where people use mercury as the main system for the gold recovery, major problem is metallic mercury. When it gets into

the air as vapour and the person inhales it. This is exactly what happens when ASGM miners torch the amalgam with gold and the mercury is boiled of as vapour. In this case, metallic mercury penetrate quickly through the blood and causes mental retardation. So if a person is exposed to mercury vapours for any length of time it can cause serious brain damages.

Unfortunately this mercury exposure is not a threat just directly to miners, but it also affects whole ASGM communities. At the risk are also infants, children, pregnant or breast feeding women. Main problem is the lack of information. ASGM miners often are not aware that usage of mercury causes those serious health problems. Even in many case if they know, they will still use this method, because it is mostly the only way how these people can earn some money for living. According expert to ASGM Richard Fuller (2014), ´As the price of gold has risen over the last decade more people have been drawn to doing this´. There is still higher number of people who are leaving farms and going to places where they can gain gold.

Long Term Impact of Mercury Use

Another issue with even worse impact of mercury use to environment occurs in long term. Again it comes from the process of boiling off mercury from amalgam. This mercury vapour settles down into the ground around ASGM miners, than the rain comes and mercury is splashed down into the local river. Natural process in aquatic systems changes this less harmful elemental and inorganic mercury to more harmful forms of mercury – the methylmercury. Methylmercury is high toxic form of mercury that accumulates and concentrates in animals and in the food chain. This is the other way how are people exposure of mercury. Local fisherman catch fish, sell it at local market and people eat it. Even the very small volume of methylmercury causes terrible damaging birth defects that can be seen for example from Minimata disease (UNEP, 2013 and Fuller, 2014).

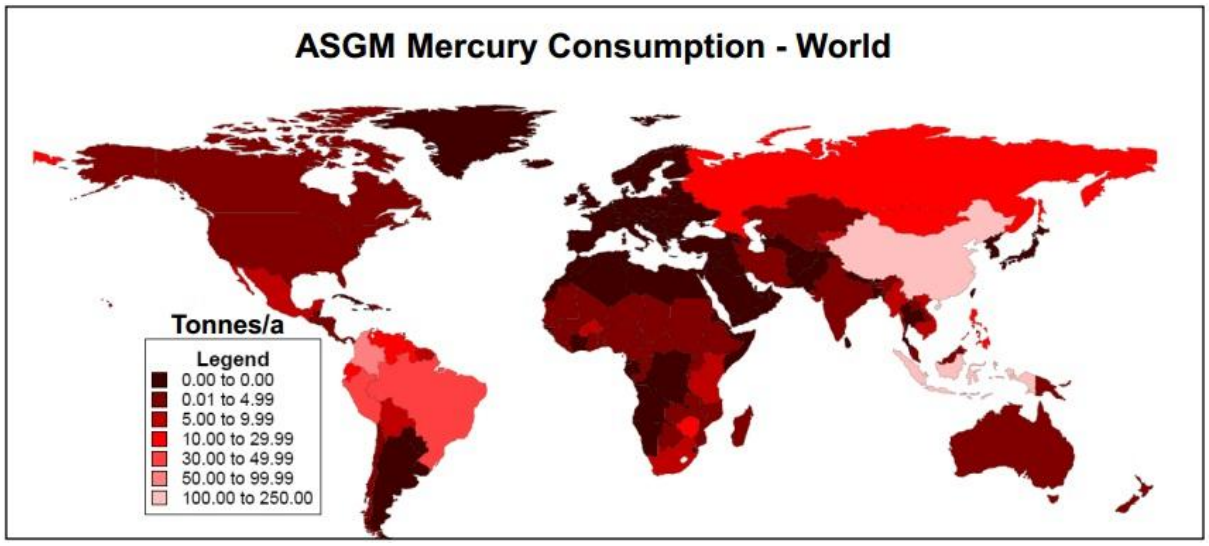
Minimata disease is a neurological condition, mercury poisons the central nervous system, damages the sense of balance and motor skills, which leads to increasingly intense body convulsions and automatically death. First occurrence of Minimata disease was in Japan in 1956, when the government find out that the Chisso Corporation chemical factory released toxic methylmercury in the industrial water waste into the Minimata Bay. People were

poisoned by high toxic methylmercury which was bio accumulated into fish and shellfish and eaten by local population (Allen and Burns, 2009).

Mercury as Global Pollutant

Another issue shows up as well. Elemental gaseous mercury can be transported globally. A lot of this mercury can go high in the atmosphere and reverse into our own seas. Then there are for example tuna fish which concentrate the methylmercury, big company caught a tonnes of tuna and distribute it around the world. And it gets us back to the problem of mercury poisoning (UNEP, 2013 and Fuller, 2014).

Figure 3: World ASGM Mercury Consumption



Source: Kevin Telmer (2008)

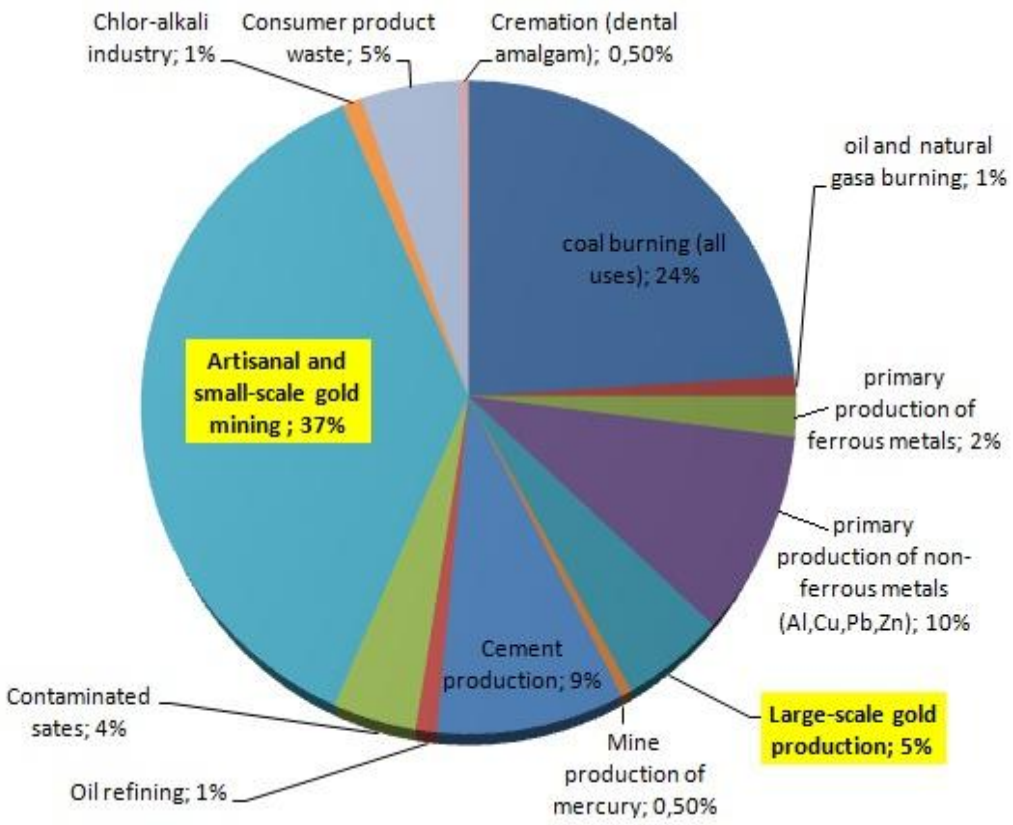
The figure shows countries according to measured mercury consumption for ASGM in tonnes. It is seen that the countries with the lightest colour of the country shows the highest consumption are mainly countries with low environmentally standards. These include China, which is according to the UNEP Global Mercury Assessment (2013), one of the largest emission contributors from ASGM. Unfortunately, the data for the last 18 years is missing. Because Chinese government banned the ASGM in 1996 and since there are no records of emissions from this sector.

3.6.3. Mercury Emissions from Anthropogenic Sources

It is important to mention, that mercury emissions do not come only from gold production. Air mercury pollution in relation to human activity is associated with a wide range of

processes. In addition that ASGM is one of the biggest polluters, it also includes manufacturing processes of ferrous and non-ferrous metals, coal and oil consumption, chemical production, iron-steel manufacturing and many others (Pirrone and Mason, 2009).

Figure 4: Air Mercury Anthropogenic Emission to Air 2010



Source: own calculations, data collected from UNEP (2013)

Chart shows all possible significant emitters of mercury emissions. According to UNEP Global Mercury Assessment (2013) total number of mercury released into the atmosphere in 2010 was 1960 tonnes. Regarding gold, this graph indicates that 727 tonnes come from ASGM and 97.3 tonnes from large-scale gold production.

4. ANALYSIS

In this chapter of Bachelor Thesis author is mainly focused on the consequences of mercury emissions to the air from Artisanal and Small Scale and Large Scale gold mining to the environment. In this paper analytical part is divided into three main sections where every section has its own subchapters.

First part is dedicated to regression analysis. It consists of two analyses. First aim is to analyse how the production of gold affects the air mercury pollution during the period of 1970 - 2008. Second goal is quantify relationship between gold production and price of gold. This part is a crucial part of Bachelor Thesis.

Another part is devoted to technical analyses focused on two technical analysis tools Simple Moving Average and Exponential Average.

Last part of the analytical section is aimed to possible solutions of reducing mercury use in ASGM. It includes several technical solutions for improvement in concentration stage in gold recovery process. This paper is mainly focused on method based on gravity concentration – shaking tables. Shaking tables are further analyzed with regression analysis using utilization of shaking tables as dummy variables. The latest part of possible solutions for reducing use of mercury is targeted on market based solutions such as taxes and subsidies or command and control solutions.

4.1. Regression Analysis

4.1.1. Relationship between Air Mercury Pollution and Gold Production

First regression model is focused on dependency between average global air mercury pollution from ASGM + LS stated as dependent variable and gold production as independent variable. From economic point of view the type of data are time series processes annually. There are 39 observations with time interval from 1970 to 2008. Data for mercury emission were collected annually from different places around the world. But within the time interval from 1970 to 2008, there were various amounts of samples, between 32,250 to 55,034 samples per year. Therefore data were processed as an average for each year.

Hypothesis

If H1: an increase in gold production in tonnes per year leads to an increase in average global air mercury pollution from ASGM + LS in tonnes per year.

Positive sign

Why: If the production of gold increases, logically the air mercury pollution will increase due to bigger consumption of mercury.

Declaration of Variables

$\mathbf{y_t}$ ... average global air mercury pollution from ASGM + LS (tonnes / year)

- y_t is further stated as M

$\mathbf{x_{1t}}$ ... gold production (tonnes / year)

- x_{1t} is further stated as Q

Estimated Economic and Regression Model

Average global air mercury pollution from ASGM + LS in tonnes per year is influenced by gold production in tonnes per year.

$M = \beta_0 + \beta_1 Q + Error$

Table 1: Regression analysis results: Average global air mercury pollution from ASGM + LS and gold production

Model 1: OLS, using observations 1970-2008 (T = 39)
Dependent variable: y_mercury_pollution

	Coefficient	*Std. Error*	*t-ratio*	*p-value*	
const	-0.00174375	0.000740011	-2.3564	0.02386	**
x_gold_production	4.91588e-06	3.77506e-07	13.0220	<0.00001	***

Mean dependent var	0.007547	S.D. dependent var	0.002859
Sum squared resid	0.000056	S.E. of regression	0.001226
R-squared	0.820885	Adjusted R-squared	0.816045
F(1, 37)	169.5717	P-value(F)	2.18e-15
Log-likelihood	207.1381	Akaike criterion	-410.2762
Schwarz criterion	-406.9491	Hannan-Quinn	-409.0825
rho	0.850006	Durbin-Watson	0.250964

Source: own calculations using Gretl, data collected from EDGAR (2008), Numbersleuth (2010), Statista (2014)

Table presents results of the regression analysis. Results clearly show that there is a relationship between average global air mercury pollution from ASGM + LS and production of gold worldwide. It is statistically significant at $p<0.05$ confidence level. There is also quite satisfying level of R^2. Variation of air mercury pollution was explained by 90.6 % with this model. So it can predicted, to a certain degree, how much mercury pollution will be created by producing extra unit of gold.

M = -0.00174 +4.91588e-06Q + Error

If the production of gold increases by 1 tonne the average global air mercury pollution from ASGM+LS increases by 4.92e-06 tonnes.

4.1.2. Relationship between Gold Production and Price of Gold

In this part of regression framework is tested the model explaining the interdependence and dependence between gold production and price of gold. An interest variable is global gold production measured in metric tonnes. As an explanatory variable is stated price of gold in units of measurement USD / ounce. Data were collected as time series data in annual intervals. Number of observations counts for 44 years. It is from year 1970 to 2013.

Hypothesis

IF H1: an increase in price of gold in tonnes per year leads to an increase in gold production in tonnes per year.

Positive sign

Why: If the price of gold increases, the gold production increases, because of the gain of higher profit.

Declaration of Variables

$\mathbf{y_t}$ ... gold production (tonnes / year)

- y_t is further stated as Q

$\mathbf{x_{1t}}$ ... price of gold annual end of period (USD / ounce)

- x_{1t} is further stated as P

Estimated Economic and Regression Model

Gold production in tonnes per year is influenced by price of gold in USD per ounce.

$Q = \beta_0 + \beta_1 P + Error$

Table 2: Regression analysis results: Gold production and price of gold

Model 1: OLS, using observations 1970-2013 (T = 44)
Dependent variable: y_gold_production

	Coefficient	*Std. Error*	*t-ratio*	*p-value*	
const	1606.93	112.11	14.3335	<0.00001	***
x_gold_price	0.782429	0.187461	4.1738	0.00015	***

Mean dependent var	1971.591	S.D. dependent var	547.7902
Sum squared resid	9120266	S.E. of regression	465.9927
R-squared	0.293177	Adjusted R-squared	0.276348
F(1, 42)	17.42085	P-value(F)	0.000147
Log-likelihood	-331.7533	Akaike criterion	667.5067
Schwarz criterion	671.0750	Hannan-Quinn	668.8300
rho	0.961017	Durbin-Watson	0.080268

Source: own calculations using Gretl, data collected from Gold price OZ (2014), KITCO (2014), Numbersleuth (2010), Statista (2014)

Results confirm the hypothesis that production of gold is related to price of gold. It is statistical significant, because p-value 0.00015 is lower than alpha 0.05. This has relatively large implications for this research as the original argument that increasing price of gold may have influence upon air mercury pollution is valid. However, more tests must be done due to low $R^{2.}$

Q= 1606.9257 + 0.7824P + Error

If the price of gold increase by 1 USD/ounce, than the gold production increased by 0.7824 tonnes per year.

If price of gold is zero, than the gold production will be 1606.9257 tonne per year.

4.2. Technical Analysis

This part of Bachelor Thesis is concerned with use of technical analysis in terms of analyse the price of gold. Briefly, technical analysis means analyzing graphs. It is an attempt to

read from past movement of share its future movement using trends, buying and selling signals. Though, there are many tools used by technical analysis, for this thesis was selected just two indicators – Simple Moving Average and Exponential Moving Average.

4.2.1. Simple Moving Average (SMA)

Kirkpatrick and Dahlquist (2011: 278) state that ´the most commonly used type of moving averages is the simple moving average (SMA), sometimes referred to as an arithmetic moving average´. It is calculated by adding the prices over a given number of periods, than dividing the sum by the number of periods. SMA reacts to current markets, so they take a little bit of time to react, shorter term moving averages are more sensitive, because they are calculating more recent data and longer term moving averages like 100 or 250 days moving averages obviously take a long time to turn in, roll over and move, because they have some much data to work with (Plessis, 2012). Generally, SMA reacts slower for the changes, than EMA, but the slower reactions, can be seen as an advantage in avoiding false signals. Investors sell the gold, when the gold price crosses below the moving average. And buy the gold, when the gold price is closes above the moving average (Václavíček, 2008).

Figure 5: Simple Moving Average, 1/2009 – 2/2015, weekly, n=40

Source: Own construction in Advinion Professional Chart, available on Investing.com, (2015)

For construction of the graph above was used simple moving average with 40 as a number of periods on weekly base. Graph shows 6 years period of gold price development. SMA trend from 2008 until March 2012 illustrates rapid increase in price, caused after Financial Crisis started in 2008. Historically the highest gold price ever was on 21 August 2011 with 1877.50 USD/oz (World Gold Council, 2014). On the beginning of 2013 can be seen a crossover, when the gold price was above the average and the price decline started. Except for few price increases in 2014 SMA still indicate downtrend of gold price. Recent data shows that the price of gold is below its SMA, which gives clear instructions to sell. Thus, it can be assumed that the gold price is going to decrease.

4.2.2. Exponential Moving Average (EMA)

Exponential moving average is the second most widely used technical indicator when it comes to moving averages. EMA gives more weight to recent prices and are calculated by applying a percentage of today´s closing price to yesterday's moving average. EMA is a little bit more reactionary, it reacts quicker than SMA (Plessis, 2012). There is same rule

for investors like the one that was mentioned at SMA. Investors sell the gold, when the gold price crosses below the moving average. And buy the gold, when the gold price is closes above the moving average.

Figure 6: Exponential Moving Average, 8/2009 – 2/2015, weekly, n=65

Source: Own construction in Advinion Professional Chart, available on Investing.com, (2015)

A look at the gold chart reveals an increasing trend in gold price till 2012. For better illustration there is indicating SMA and EMA together. Red line of EMA shows quicker reactions for changes in market of exponential moving average Even this graph of EMA was constructed with different number of n period than the previous chart of SMA there can be seen very similar graph pattern. The most recent price is below the EMA and as well as SMA gives a signal to sell.

4.3. Possible Solutions for Reducing Mercury Use

This part of bachelor thesis is dedicated to possible solutions for reducing use of mercury in Artisanal and Small Scale gold mining. First part of possible solutions chapter introduces some of technical solutions, with closer focus on one of the technology – shaking tables. Another part presents usage of shaking table in practise. And analyze if there is any significant difference in air mercury pollution from gold mining because of utilization of these concentration based tables. Very last part suggests some of market based and command control solutions in terms of reduction mercury emission.

Generally, it is necessary to reduce the amount of mercury used in ASGM. These reductions are more likely to be accepted by miners only in case that income of miners will be higher or at least at the same level as before. There are many ways in conformity with Telmer and Stapper (2012) how the reduction can be achieved including following points:

- Costs can be saved by maintaining or eliminate the need for mercury
- Use of better technology or use existing technology with more efficient way, can improve the gold recovery
- More effective processing for time saving
- Miners would receive cash premium for proper extracting practices (fair-trade mechanism). For example, due to the influence of organizations such as the Alliance for Responsible Mining (ARM) and the Fair Trade Labelling Organization (FLO)

4.3.1. Technological Solution

In this subchapter of bachelor thesis the author agrees with several possible solutions suggested by Telmer and Stapper (2012) which they introduced in book Practical Guide of Reducing Mercury Use in ASGM and with some technologies described by Ish Grewal in his article Mineral Processing Introduction.

Improving Concentration

As was already mentioned gold occurs in rocks as free particles, but in most cases gold is a part of another mineral. Therefore, before it is possible to improve the concentration stage, gold must be separated from the rock. This is achieved using "comminution", which is the

technical term for rock crushing and milling into a powder. Although it may not seem grain size is very important.

Firstly the crushing step is applied. In ASGM it is most often performed manually or in some cases can be used techniques so called jaw crushers. But because the crushing stage usually does not create the necessary powder, therefore, the second stage of milling occurs. In general, it may be summarized that small scale miners use two types of milling. It is wet milling, where the name itself says in the presence of water. The second type is dry milling where the use of water is not necessary, but it produces huge amounts of harmful dust, which is very dangerous to both the workers and other community members including children.

Concentration is an indispensable process in gold extraction. This is why this step is so important, because if it is done well, there can be seen significant reduction or even exclusion of mercury use. Although the concentration may be accomplished in many different ways, the most common method for the concentration is gravity separation. This effectively separates heavier grains of gold from lighter particles. Producing a concentrate depends on the size of grain, ore type, access to finances and know-how about the equipment purchase and usage. There exists many types of concentration technologies, but this thesis is focusing on selected technologies described below.

Sluices

One of the improving techniques for gold recovery are sluices. The principle on which the sluice work is the use of water flow on sloping plateau covered with a rough surface, usually a carpet that captures the precious gold. Because gold particles are much heavier than the other sediments in the sand, gold sink quickly to the bottom of the downstream, whereas light particles are carried downwards, away from the sluice.

To improve gold recovery in some areas are used so-called Zigzag sluices. It raises the possibility of capturing the gold particles by being divided into several inclined platforms through which water flows, with sediments.

Centrifuges

As the name suggests centrifuge works not only on the principle of the centrifugal force, but again relies on the fact that gold has a heavier specific density than other particles. Into the rotating drum is usually puts about 60-75% of water and 25-40% of ore. The walls of the drum are covered with a series of ridges, where heavier particles get stuck while the drum rotates and lighter parts are discharged with the flow of water away from the centrifuge as tailings. Then the concentrate must be cleaned up from the ridges.

There are many different centrifuges, which differ both in design and price range. Their application requires general conditions such as: really small grains of ore, which requires quality milling; it is necessary the supply of power and water; and one of the main conditions is quite high initial capital (around several thousand dollars).

Spiral Wheels

Another technology Improving concentration and mercury use reduction is spiral wheel or so Called spiral concentrates. It is a machine with great special tilted spinning pan that has on its surface spiral shape ending with the hole in the middle. There is a tube with holes above the spiral that continuously delivers water. The concentrate is added manually by spoons to the bottom of the pan. From there the sediments with gold get up in a spiral, but the hole in the middle of the pan reaches only gold that is heavier than tailings, which are washed back down by water.

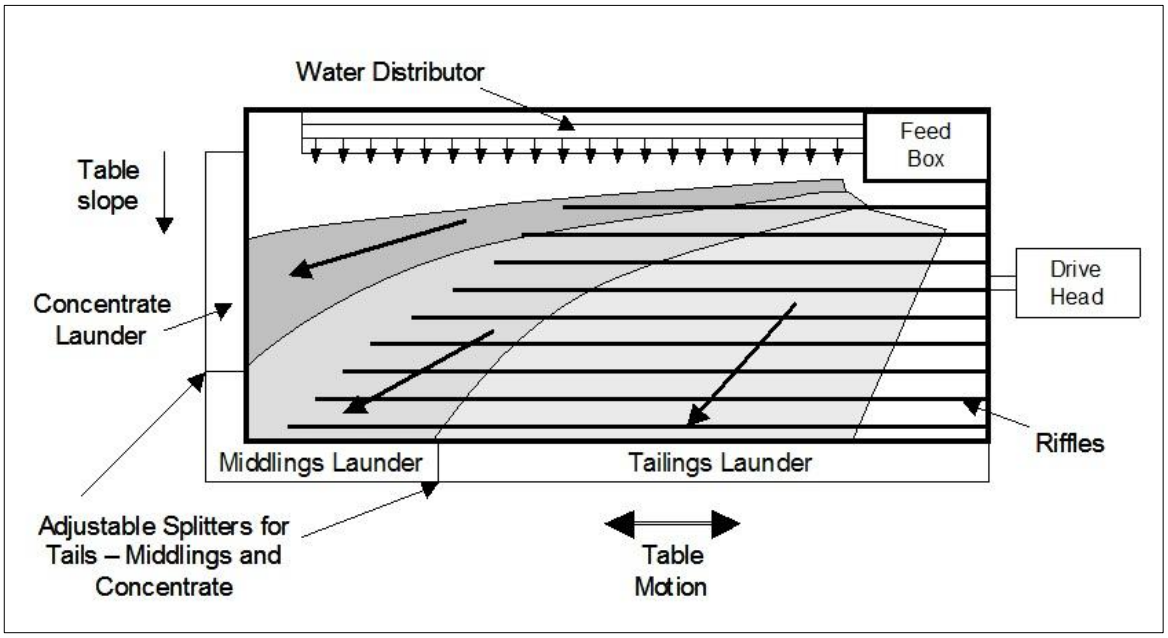
Vortex

Vortex is technology producing high quality concentrate that can capture fine gold. One big advantage of this method is simple to use and very low price. Again, it works on the principle of gravity. The main part is the bowl about 30-50cm, from the side leads hose bringing strong stream of water into the bowl, creating a whirlpool. In the middle of the dish is a few centimetres elevated hole, where are discharged lighter particles by water pressure. Gold remains on the bottom of the bowl, because it is significantly heavier than the rest of sediments. Best results are in pure water, but especially in ASGM it is rather impossible.

Shaking Tables

Shaking tables, as environmentally friendly method of gold extraction is widely utilized in most countries.

Figure 7: Shaking table description



Source: Grewal (2014)

As the name says shaking tables are shaking desks that on the basis of gravity and weight diversity of minerals separate gold particles from other minerals. Continuously shaking desk is driven by a motor, is inclined and over the entire surface has horizontal riffles. Water is fed around the top edge and in the upper corner is located mineral feed box. Due to shaking motion, the riffles and flow pointing to the lowest corner diagonally across the table, minerals are sort. Firstly, lighter particles are washed over the riffles, while heavy particles are carried across the table to concentrate pickers. Shaking tables creates high gold rich concentrate, usually greater than 50%. However, the gold still must be sent to further extraction from the concentrate, for example by gravity process, the direct or chemical smelting.

One big disadvantage of shaking tables is their high initial cost, technical knowledge, need for the water and the energy. Following Telmer and Stapper (2012) the estimated cost per

table is between 1,000 to 10,000 USD. However, this depends on many other factors such as the size, quality, quantity, performance of the table and so on.

In 2011 ASGM was estimated to use 1,400 metric tonnes of mercury. With mercury price of $ 2,550.15 per tonne (Recycle in me, 2014), cost for using it can be calculated at 3.57 million USD in 2011.

4.3.2. Government Based Solutions

It cannot be forgotten to consider possible solutions to reduce the use of mercury in extracting gold in ASGM impact of market based mechanism.

Firstly, the government as an authority should be able to identify how much serious and hazardous is using mercury in ASGM to the environment. The government should take care of awareness of the threat connected with mercury use. Everyone, not only miners but also other residents should be aware of the devastating consequences that related to the usage of mercury. It concerns both inhaling vapours from amalgamation and water and air pollution.

Market Based Solutions

Another possible solution is market based solution. Government should increase taxes for the sale of mercury. Taxes should be high enough that miners stop with mercury usage. But here is the risk of a black market and illegal trade. A better solution might be subsidies. For example, subsidies for using mercury free technology - like shaking tables. Or, as mentioned earlier in this work, the workers who would use environmentally friendly methods would receive special subsidies from the government.

Command and Control Solutions

Another solution that is offered is command and control solutions. The government may partially prohibit the free sale of mercury. Of course complete ban is irrational, because there is a problem with enforcement and monitoring.

In developed countries the mining related mercury emissions decreased over recent years not only due to strict policies, but also because of an introduction of new control mechanisms and developed technologies. In Canada, emissions from mercury decreased by 84% between years 1990 – 2009. 80% decrease was recorded in the U.S. from 2002 to

2005. And also in Europe were significant decrease in mercury emissions due to changes in economics and control measures improvement (Mining Facts, 2014).

5. RESULTS AND DISCUSSION

5.1. Regression Analysis Summary

With the first regression framework was found that there is a relationship between average global air mercury pollution from ASGM + LS as dependent variable and gold production aka independent variable. Results also show quite strong R^2 reporting 90.6 %. Very interesting is the finding that if the production of gold increases by 1 tonne the average global air mercury pollution from ASGM+LS increases by 4.92e-06 tonnes.

The second part of the regression analysis was to investigate the dependence between price and gold mining in last 44 years. However, it must be taken into account low value of R^2. According to results, it is statistical significant so there is a relationship between these two variables. Can be said, if the price of gold increase by 1 USD/ounce, than the gold production increased by 0.7824 tonnes per year. This is especially crucial outcome of this work. Previous regression showed that gold production is in dependence on the mercury pollution and now it is known that the production of gold is associated with the price of gold. Therefore, it may be assumed that the price of gold affects environmental quality.

5.2. Technical Analysis Summary

In the technical analysis was examined development in the gold price using tool of moving averages. Firstly with SMA, it can be clearly seen uptrend in gold price since 2009 as a result of the financial crisis until 2012, where it is the tipping point and gold started its predominantly downward trend. The latest data shows again signal to sell the gold, because the price of gold is below its MA. Hence, it can be assumed that the gold price continue to decline. The same tendency also shows a graph with EMA.

5.3. Possible Solutions for Reducing Mercury Use Summary

In chapter focused on solutions to reduce air mercury emissions from gold mining, was suggested several solutions. Firstly there is a technical solution directly orientated towards improvement in the concentration phase in ASGM. The most important design is usage of shaking tables, which separate gold particles from lighter sediments. While the use of shaking tables require additional method for the extraction of gold still it is very effective.

The last part deals with the solution coming under the government. Author suggests, for example, high taxes for the use of mercury or a partial or even complete ban of free usage. However, it cannot be forgotten, that the artisanal and small scale gold miners would use method which is the most economical for them.

6. CONCLUSION

Bachelor thesis, Influence of Gold Price upon Environmental Quality, met its desired goals. The first part is about introduction to gold, its development and use. Strong emphasis is placed on gold-producing countries and on gold production, focusing on ASGM and its mining techniques using toxic mercury. On the basis of the UNEP air mercury anthropogenic emission 2010, ASGM together with LS contributed the largest part of that kind of pollution.

The regression analysis implies that mercury air pollution from ASGM + LS is interrelated with gold production. If gold production increases by 1 tonne per year, mercury pollution increases by 4.92e-06 tonnes. Second regression proves the relationship between gold production and its price. If the gold price rises by one UDS/oz, then gold production increases by 0.7824 tonnes/year. This is a very crucial step in this work, according to which the author concluded, the price really affects the quality of the environment.

With the use of moving averages has been demonstrated that the gold price is below the average, which indicates future decline in gold prices. Among the possible solutions proposed for reducing mercury usage in ASGM, shaking tables were selected as the best alternative. Although their purchase price more expensive than other techniques, resulting price of mercury consumption is much higher. Another very important solution is the attitude of the government on the matter. It could, for example, raise taxes for mercury use or prohibit its sale.

Thus, for overall summary, the higher is gold price the greater are risks to environment, depending on expanding gold mining. The question is whether, mostly developing countries focusing on gold production will be willing to accept more environment-friendly technology of mining, while the demand for gold is still increasing.

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8. APPENDIX

Appendix 1: Data set of gold prices, production of gold and air mercury pollution used for regression analysis

	Gold price	Gold production	Average air mercury pollution (ASGM+LS)
year	USD / oz	t	t
1970	36	1480	127.680843244499
1971	41	1450	126.341881895189
1972	58	1390	123.545567869078
1973	97	1350	150.587410385487
1974	159	1250	149.107655163221
1975	161	1200	132.340190115484
1976	125	1210	117.42734220081
1977	148	1210	116.836884441158
1978	193	1210	118.090461920968
1979	307	1210	124.971139973101
1980	612	1220	141.210691939593
1981	460	1280	173.568915349157
1982	376	1340	183.601600753025
1983	424	1400	190.413746268791
1984	360	1460	231.007339889238
1985	317	1530	256.516938130949
1986	370	1610	269.396983243976
1987	446	1660	268.146547280402
1988	437	1870	288.853154062889
1989	381	2010	310.076076048072
1990	383	2180	341.937469093609
1991	362	2160	365.926188709059
1992	344	2260	392.247930552214
1993	360	2280	405.516664618321
1994	384	2260	408.842800699508
1995	384	2230	410.495238920429
1996	388	2290	421.984281085144
1997	331	2450	448.263296641172
1998	294	2500	447.587566147846
1999	290	2570	452.738765115607
2000	274	2590	450.454136642797
2001	276	2600	443.324199426463
2002	347	2550	437.239643589966
2003	416	2540	439.809133713223
2004	435	2420	466.801649857128
2005	513	2470	453.781157866936

2006	632	2370	453.967945054504
2007	833	2360	457.828450043971
2008	869	2290	456.274624059888
2009	1087	2450	
2010	1405	2500	
2011	1531	2660	
2012	1657	2660	
2013	1204	2770	

Source: own table, data collected from Gold price OZ (2014), KITCO (2014), Numbersleuth (2010), Statista (2014), EDGAR (2008)