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BOTSWANA INSTITUTE FOR DEVELOPMENT POLICY ANALYSIS

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2014

**BIDPA**

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**ABSTRACT**

This paper considers the development of synthetic gem quality diamonds and the potential impact on Botswana, the world's largest producer of mined diamonds by value. The paper considers the rapid growth of CVD diamonds in the past 20 years and argues that there is reason to believe that given the market conditions prevailing in the mined gem quality diamond industry, synthetics do constitute a serious threat to the industry. There is consideration of the price decay function in light of the experience of synthetic industrial diamonds as well as the impact on mining tax revenue. There is an analysis of the various actors in the diamond industry and their response to synthetics. Policy responses to the threat of synthetics are considered in the final sections. While the diamond and jewellery industry has responded to the threat of synthetics, there has been no attempt to address the most serious risk, which is the possibility of a sudden and catastrophic loss of confidence by consumers in the long term market value of diamonds. The paper argues for mandatory global documentation and disclosure of mined and synthetic diamonds.

*"If we could succeed, at a small expenditure of labor, in converting carbon into diamonds, their value might fall below that of bricks." Karl Marx , Das Kapital, Volume I, Section I, 1864 (not quite yet!)*

## EXECUTIVE SUMMARY

There exist numerous economic reasons why the threat posed by the recent improvements in the production of synthetic CVD diamonds in particular should be of concern to Botswana and other large mined diamond producers. These include:

**1.** The Supply-demand mix that is developing in the global market for gem quality diamonds is creating a situation where given the success of the marketing campaigns of De Beers and other diamantaire, the demand for diamonds has been rising while supply of mined diamonds is unlikely to rise at a sufficient rate to keep pace with the growth of demand in emerging markets such as China and India.

**2.** The market structure of the industry has changed and De Beers, once a cartel controlling 80-90% of global production, has contracted and is now unable to dominate the market and control supply of either mined or synthetic diamonds as was the case in the 1980's and early 1990's. Moreover, the technology for producing synthetics is now widely diffused.

**3.** While ethical, human rights and conflict considerations regarding the production and processing of mined diamonds are not a consideration in some markets, they certainly are in many of the more advanced markets and the experience of conflict diamonds, along with the industry's unfortunate association with gross violation of labour and human rights, dented the image of mined diamonds in 1990's

**4.** Scientists have attempted with more or less success to create synthetic gems including rubies, emeralds, sapphires and pearls. The most successful emulation has been that of pearls, where cultured pearls have come to completely dominate the pearl market. Cultured pearls have much in common with synthetic diamonds in that simple detection of synthetic or cultured products is not straight forward and hence market differentiation is difficult.

**5.** The new production techniques for CVD diamonds in particular are resulting in the production of diamonds that have qualities often superior to that of mined diamonds for the purposes of industrial application. The potential for industrial application will, in the coming years, be one of the main long term drivers of new synthetic developments, though profits from the development of synthetic gems will drive the industry in the short to medium term.

**6.** Synthetic industrial diamonds have existed since the 1950's and the technology was originally controlled by De Beers (Element 6), and later by GE and Sumitomo. The experience of synthetic industrial diamonds was that the three synthetic producers flooded global markets and prices collapsed over a 30 year period. These companies no longer monopolise the technology for the production of synthetics and it has been widely diffused. Indeed the world's largest producer by volume of diamonds is neither Botswana nor Russia, but China, which produced 4.4 billion carats in 2008.

### Risks to Botswana

Being the world's most diamond dependent economy, the risks posed by the development of relatively low cost synthetic gem quality diamonds to Botswana are considerable as they potentially diminish the profitability of the mining operations in the country. The government of Botswana owns 15% of De Beers and 50% of the local mining subsidiary Debswana which is responsible for 70% of De Beers output. Approximately 40% of 2012 government revenues came directly from the taxation and profits from the diamond mining industry. The analysis has not modeled the impact of the possible price decreases that could occur as a result of the wholesale introduction of synthetics into the value chain, as there exists no obvious price decay function based on previous experience as in the case of decay of the price of industrial diamonds. A sudden loss of confidence in diamonds as a store of value which would come from a realization by consumers that virtually identical products can be mass produced in a laboratory, and that diamonds are no longer scarce cannot be discounted.

This would immediately be translated into sustained decreases in Botswana government revenues.

**Responses of Stakeholders**

The measurement of the value of diamond is based on the well-known 4Cs - cut, clarity, colour and carat weight. The management of synthetics and their potential penetration, nefarious and legitimate of the mined diamond market is governed by the four Ds - Differentiation, Detection, Disclosure and Documentation. Without detection, disclosure and documentation, product differentiation between two virtually identical products is not possible. However, as we shall see, some of the practices of the jewellery industry such as synthetic anealment exacerbate the problem by blurring the conceptual distinction between synthetic and mined diamonds and this, rather than nefarious penetration of the value chain, could well constitute the greatest single risk to the viability of the market.

**a. De Beers**

De Beers has gone through three stages of response to the development of synthetics. The first was in the 1990's when it established the Gem Defense Fund and started developing new machines that would assist 'diamantaire' to differentiate synthetic from mined diamonds. The second came with the development of its Supplier of Choice Strategy in 2000 which attempted to enhance its market power and that of its sight holders through enhanced marketing and branding strategies. De Beers has now entered a third stage where its synthetic producing subsidiary 'Element 6' has begun to patent gem quality diamonds.

**b. The Jewellery Industry**

The jewellery industry has responded to the challenge of synthetics in both a positive and negative manner. It has also tried branding its products resulting in trademarks that assure that those products are not counterfeited. However, there is increasing evidence of the nefarious penetration by synthetics of the jewellery market and moreover, the industry has been using synthetic techniques to enhance and anneal mined diamonds to improve their clarity and colour. This practice, while documented by standard setting agencies, eventually eliminates the conceptual distinction between the two products and makes product differentiation all the more difficult, if not impossible.

**c. Standard Setting Agencies**

Institutions like the Gemological Institute of America and similar voluntary standard agencies around the world have developed voluntary reporting standards and codes which assist in the differentiation of the mined and synthetic products. However, there is no obligation to comply and these standards are not universal. There is abundant evidence that there has already been significant nefarious penetration of the jewellery market by synthetic diamonds and yet the industry in the US and EU has never publicly disclosed the extent of the entry.

**d. Botswana**

Botswana has responded to the threat of synthetics in 2004 by signing an agreement with De Beers that should it ever go into the production of synthetics it would form a Joint Venture with Botswana. However Botswana's known reserves of diamonds are in decline, and are expected to decline sharply after 2026/27. The optimal policy would naturally be one of resource conservation if it were not for the unknown timing of price effects of synthetics on mined gem quality diamonds.

It is unambiguously in the interest of Botswana and other mined diamond producers to move away from voluntary to mandatory disclosure of mined and synthetic diamonds along the value chain. However, to

achieve support from the international community for such a starndard, it is first necessary to demonstrate that misidentification occurs. Such studies have already been undertaken in Japan, but need to be undertaken on a global level. However, the results of such a study would almost certainly destabilise the diamond market in the short term and temporarily decrease profitability along the value chain, including revenue for the mined diamond producing countries.

## ACRONYMS

| | |
|---|---|
| 4C's | Cut, Clarity, Colour and Carat |
| 4D's | Differentiation, Detection, Disclosure and Documentation |
| CVD | Chemical Vapor Deposition |
| DTC | Diamond Trading Company |
| EU | European Union |
| GDP | Gross Domestic Product |
| GE | General Electric |
| GIA | Gemological Institute of America |
| HPHT | High Pressure High Temperature |
| JV | Joint Venture |
| LVMH | Louis Vuitton-Moet Hennessy |
| SADC | Southern African Development Community |
| US | United States |
| USA | United States of America |
| USD | US Dollar |
| USGS | United States Geological Survey |

## 1. Introduction

The purpose of this paper is to analyze the potential impact of the development of synthetic gem quality diamonds on the mined diamond sector and the revenues of the Government of Botswana. Botswana, prior to the economic crisis of 2008/9, was the world's largest producer of diamonds by value. Botswana produced approximately 33 million carats of diamonds per annum in 2008 and, of this, approximately eight million were industrial diamonds. By 2013 Botswana was producing some 31 million carats and has in effect recovered to pre-crisis production levels. Depending on the particular year between 25-40% of Botswana's total tax revenue is derived from mining, almost all of which are from diamond mining[1]. Given that the diamond value chain has high recorded profits at two points, mining and retail, the advent of synthetic gem quality diamonds and the impact on prices, mining profits and, hence, government revenue should be of great concern to economic planners and the Government of Botswana.

Over the past 30 years, synthetic diamonds have grown in such importance in their industrial uses that mined diamonds now constitute a little over 1.5% of total world supply of industrial diamonds (US, 2013). This paper poses the question of whether the recent technological developments in synthetic diamond production and enhancement of mined diamonds and their increasing high technology application which require qualities of colour, clarity and carat size similar to that of gem quality diamonds, will not result in a similar displacement of mined gem quality diamonds in the coming decade.

The answer to the question lies in several factors that remain unclear at this point. The first question is whether synthetics diamonds will have the effect on the market that the development of cultured pearls had on the pearl market, where they simply replaced natural pearls almost entirely or whether they will replicate the market experience of synthetic rubies and emeralds where the mined and synthetic markets are separable and there has been no appreciable long term effect of prices of natural stones. From what little reliable evidence exists, synthetics constitute a very small portion of total gem production[2]. If the two markets are not effectively separable, then the life cycle of gem quality synthetic diamonds will follow the experience of industrial diamonds. There has already been a mapping exercise undertaken of synthetic industrial diamonds - the market for which is considered to be at a stage of either decline or potential renewal (Phaal *et al,* 2010). The application of Chemical Vapor Deposition (CVD) technologies suggest a renewal of the sector and the potential for a new, much vaunted 'diamond age', especially given the massive surge in technological research on the application of the new diamond materials. A further important question is whether there will be any possibility for De Beers, which has been a dominant player in both synthetic and mined diamonds, to control supply to the market. There remains the on-going question of the acceptability of synthetic as opposed to mined diamonds in jewellery use by consumers. It is precisely the substitutability of synthetic and gem quality diamonds in the calculation of consumers that will ultimately determine whether virtually identical synthetics and natural gem quality diamonds are substitutable in end use in their most important market which is in jewellery production.

The paper proceeds by first considering the reasons why synthetics must be seen as a serious cause for concern for mined diamond producers and especially so for the world's largest producer by value, Botswana. The second section considers briefly the implications for Botswana's tax revenue in the event of a decline in diamond export prices under assumptions regarding the rate of price decay and the point in the life cycle based on the experience of industrial diamonds. The third section considers the response of various stakeholders in the mined diamond and jewellery industry to the threat posed by synthetics, as well as some of the policy options available to mined diamond stakeholders in maintaining market values.

[1] This figure is based on Bank of Botswana data for 2007, prior to the onset of the international economic crisis. In the same year, the government's share of total Debswana profits was Pula 9.3 billion, equivalent to approximately 30% of total government revenue. By 2010/11, estimated mineral revenues including royalties and dividends, as well as taxes were approximately 27% of total tax revenues.

[2] The only secondary data on volumes is anecdotal in nature and dated. In 2006 the Wall Street Journal estimated that there were 400,000 carats of synthetics sold in the US as compared to a global production of 130 million carats of mined diamonds. See 'Gem War' –O'Connell V. in Wall Street Journal 13th January, 2007, page 1 http://online.wsj.com/article_print/SB116864778950975802.html.

## 2. Why are Synthetics of Concern to the Mined Diamond Industry?

This section looks in some detail at the reasons why synthetics have become an issue for the mined diamond sector at this particular time. It is a result of a confluence of events including the failure of the mined sector to add to supply just as the diamond marketing companies have succeeded in transforming marriage rituals and demand for diamonds more generally in rapidly developing countries like India and China where precious stones and metals such as gold and jade were long seen as central to the marriage ritual of those increasing numbers of individuals able to afford such commodities. Second De Beers, the former cartel operator and currently the dominant oligopolist in the industry has been in long term decline thereby restricting its ability to control prices and the advance of new synthetic technologies as was the case in the past. Significantly synthetic diamonds, especially CVD diamonds, share with pearls important technical and market qualities that would render them difficult to segregate into a particular market. Another important reason is that the jewellery industry has proven most adept at increasing profits by improving the quality of mined diamonds through synthetic techniques such as anealment which blurs the distinction between mined and synthetic diamonds. Perhaps the most important reason for concern was the experience over the last fifty years of the industrial diamond market where the entry of synthetics has resulted in massive decline in unit prices in the United States (US) and other markets.

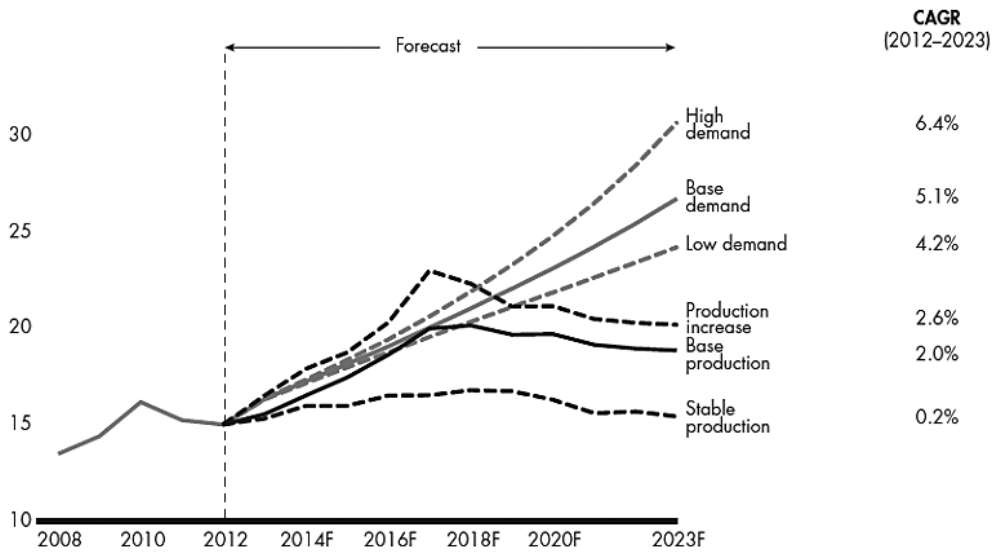
### 2.1. The Supply/Demand Balance of Mined Diamonds

Perhaps one of the main reasons for concern regarding the possible impact of the new wave of synthetics is the emerging gap between the supply and demand of mined gem quality diamonds through the present decade. The figure below presents what has certainly been seen as the consensus, albeit a self-interested one, of the mined diamond as well as the jewellery industry. Analysts almost universally agree that there is an emerging excess demand for gem quality diamonds (Kilalela, 2008). The projected growth in demand, fuelled in no small part by the growth of income and demand for gem quality products in the emerging Asian and Middle Eastern markets along with successful advertising campaigns in key urban markets that have shifted demand to diamonds as a result of the mimicking of western marriage rituals rather than those using traditional items such as gold or jade. Indeed, the projections may well be quite realistic and will certainly impact the degree to which synthetics will become more acceptable to consumers. Al Rosa for example argues that 'The anticipated gap between the expected supply and demand for rough diamonds can be closed by a 31% growth in rough diamond prices by 2018 relative to 2008 prices (or a 55% growth if the US dollar inflation of 2-2.5% per year is taken into account)[3]. All that varies in the analysis of analysts is the precise timing of the emergence of the excess demand. In the Bain and Co analysis below, even assuming the high rate of growth of supply i.e. 2.6% and a low rate of growth of demand i.e. 4.2% significant excess demand for diamonds is likely to appear around 2018. It has been normally assumed that the excess demand will generate significant increases in prices but increasingly there is the view that the excess demand will result in a higher rate of penetration of synthetics into the market which may well result in a decrease in prices at the bottom end of the gem quality diamond market.

Assuming that these long term projections of excess demand are in fact correct, the shortage of mined diamonds presented in the figure below will create a natural space for synthetics which, depending largely upon consumer acceptability, could grow to represent approximately one third of the gem quality market by 2018. Indeed, the excess demand for mined diamonds may well be the factor that finally precipitates a substantial entry of synthetics into the jewellery market and may well be associated with long term decreases in price, rather than the increase.

[3] AlRosa 'Diamond Market Outlook' June 2010. While the estimates of the magnitude of the excess demand in the industry varies from firm to firm in the diamond industry the Alrosa projections are approximately a consensus throughout the diamond industry. It should be noted that since these projections the global diamond market has continued to feel the effects of the Global Economic Crisis but prices have risen sharply in 2011.

**Fig. 1: Industry Supply and Demand Projections for Rough diamonds (2009-2023 in US billions)**




**Source:** Bain and Co. 2013

Why has supply been so limited and why is there so little mined production? The existence of diamonds in nature is a relatively rare event and hence finding diamonds has historically been extremely difficult and expensive. However, the specific situation stems from the existing mines and their development. In particular, the reasons for declining supply include (Read and Janse, 2009) :

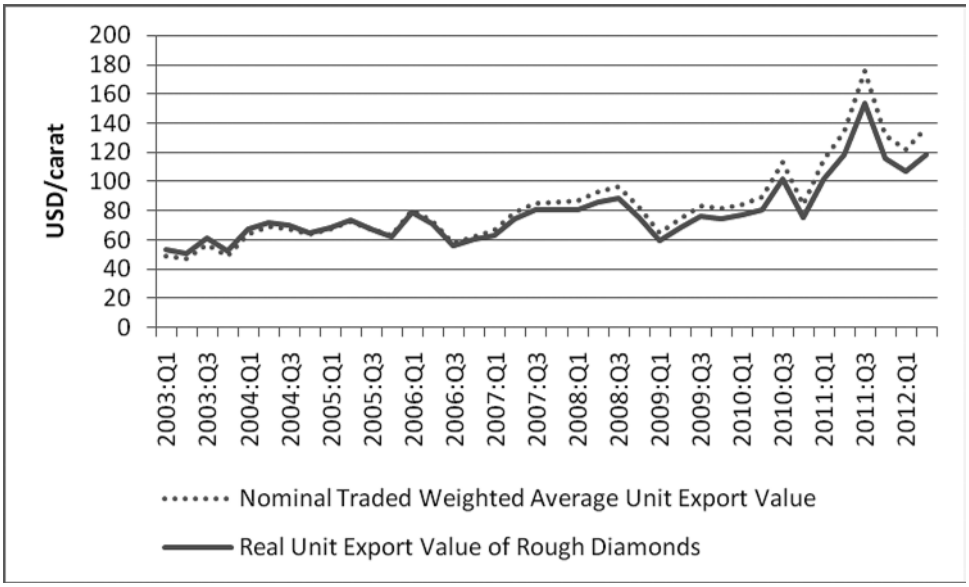
**a.** Old mines are closing or being redeveloped (e.g., Kimberly and Culinan)

**b.** Several mines are in transition from open pit to underground (Argyle and Ekati )

**c.** New mines have tended to be smaller (Snap lake and Victor) than the mines that have driven the industry for three decades (Jwaneng, Orapa and Udachnaya)

The figure below depicts the rising nominal and real prices for rough diamonds on the world market. The data is based on unit export values for diamond producing countries since 2003, and is based on data available on the Kimberly web site. What is particularly significant about the data is that it indicates that the average unit export values have continued to rise even in the long term, even in the face of the global economic crisis. This rise in unit export values even after inflation suggests that despite the decline in global demand during the on-going economic crisis diamond prices have maintained real and nominal value and indeed confirm what industry analysts suggest, namely that diamonds are increasing in unit value terms and the projections of diamonds analysts are likely to be accurate.

**Fig. 2: Nominal and Real Unit Export Values of Rough Diamonds**




**Source:** Kimberly Process, NB Prices are deflated by the US GDP deflator (2005=100). Unit values are calculated for exports of major diamond producing countries. The data excludes India and China which re-export very large volumes of non-originating rough diamonds.

The significant decline in mined diamond production in the De Beers group (i.e. Botswana, Namibia, Canada and South Africa) in the wake of the 2008 global recession may be sufficient to explain the strong price rebound even during a severe global recession. However, there have been no new large diamond mines discovered in the last fifteen years, and as a result, this price trend could in part be due to declining production and reserves in existing mines.

The emerging excess demand for diamonds combined with an increase in the supply of synthetics stemming from improving HPHT and CVD diamonds means that synthetics are expected to play an increasingly significant role in the coming years in meeting a growing demand from numerous sources. However, the growth of synthetic diamonds in the international gem quality diamond market and their potential effect on gem prices in future means that there will be a feed through loop to the mined diamond sector which could accelerate the decline of the latter. The gestation period on mining projects in the diamond sector is long, often as much a decade from initial exploration work to development of the mine and export of the diamonds. The uncertainty created by synthetics and their decreasing cost of production both in gem and industrial uses decreases the expected profitability of further exploration for mined diamonds. Moreover, the possibility that Element 6, the De Beers subsidiary, which has developed industrial diamonds and CVD diamonds in particular, will enter the gem market further retards the interests of those smaller mining companies that are normally involved in exploring for more mined diamonds[4]. Indeed, as we shall see below, the projected shortage of gem quality mined diamonds in the current decade may well be the impetus to the development of synthetics in the same way that the price boom of industrial diamonds in 1980-81 was a precursor to the secular decline of industrial diamond prices.

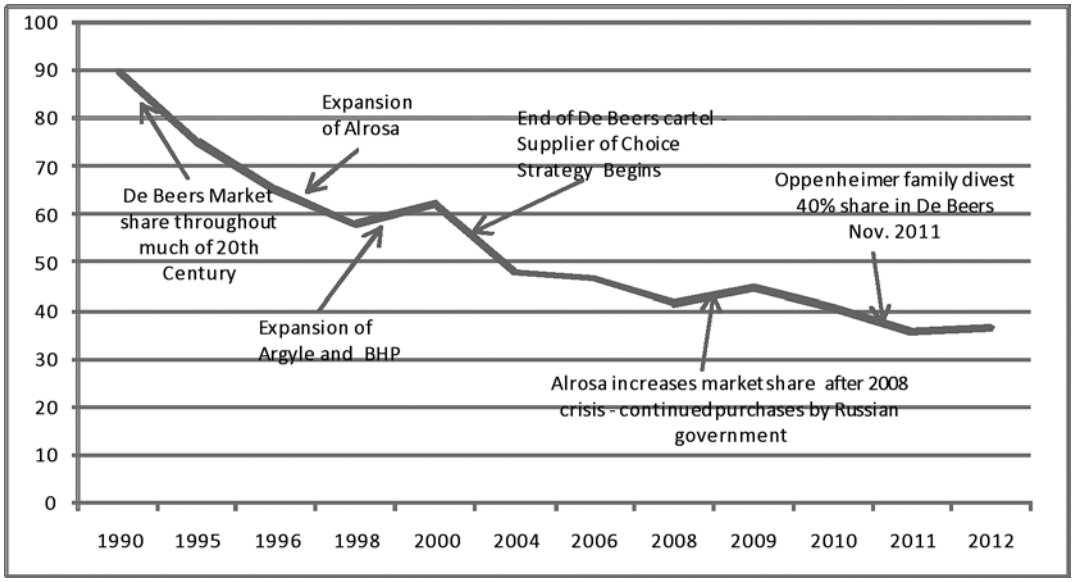
### 2.2 Market Structure - Gem and Industrial Diamonds

De Beers existed as a cartel throughout much of the 20th century and controlled approximately 80-90% of the market until 1990. It formally ceased to be a cartel in 2000. In the past De Beers had substantial control of both synthetic production as well as mined output. The figure below depicts the decline of De Beers' market share in the gem quality market over the last twenty years.

[4] ibid page 9.

De Beers has metamorphosed from a cartel into a dominant oligopoly in the gem market, where, despite the market shares of the other major producers (Al Rosa, BHP Billiton, and Rio Tinto), it remains the most significant market actor (Gupta *et al*, 2010). Despite the oligopoly in the sector, there is no evidence that these firms collectively set mined diamond prices. The increasingly complex and competitive market for both mined and synthetic diamonds means that the development of CVD diamonds, as a gem quality product, should be of greater concern to the mined diamond producing countries in the SADC region than previous synthetic developments, because De Beers is no longer in a position to control either the mined or synthetic markets and no longer controls the technonolgy to produce synthetics.

**Fig. 3: The Decline of De Beers Share of the Gem Quality Market**

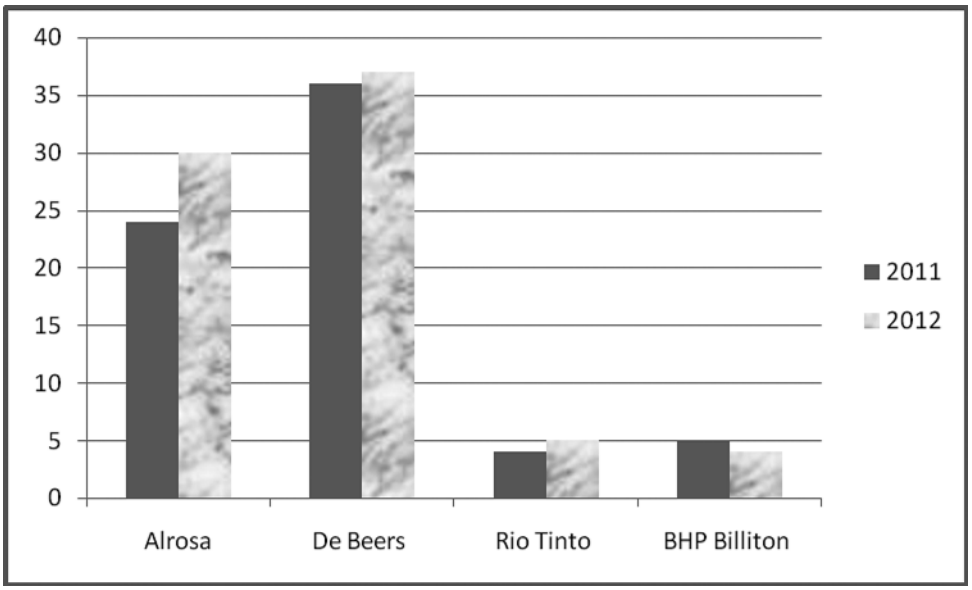



**Source:** European Commission (De Beers – LVMH Decision 2001 Official Journal of the European Commission), De Beers Annual Reports, RBC, Bain and Co 2013, Authors' estimates

Since the creation of the first synthetic diamonds in the early 1950's, the initial gem diamond market reaction to any new invention or enhancement process has generally been one of great concern. This was true both then and after 2004 with the development and marketing of Apollo[5] CVD Diamonds. The long standing concern in the diamond industry regarding synthetics and their impact on gem quality price has thus far proven to be unjustified (Spar, 2006). What was exceptional about the Apollo CVD diamonds was that they had produced and patented (in the US) a method for growing gem quality diamonds with flawless crystal structures (Olson, 2005). The initial discoveries occurred in an environment where the market for both natural and synthetics was largely controlled by De Beers. Post 2000, with the diamond market being far more competitive, the technological change is now a greater risk to the mined diamond sector than in the past.

[5] http://www.apollodiamond.com. In 2007, in a presentation in London Apollo indicated that its production target was 1 million carats per year by 2014. CVD diamonds had been in existence since at least the 1950's, alongside HPHT diamonds. Apollo began marketing gem quality CVD diamonds, but they had only been used for industrial purposes and not for the gem market.

**Fig. 4: Market Share of Rough Diamond Production By Firm by Value**




**Source:** Alrosa, De Beers, and authors' calculation.

While De Beers and its rebranded industrial/synthetic subsidiary, Element 6, were and remain very much at the forefront of the invention and development of CVD diamonds, De Beers' publicly stated intention in the 1980's and 1990's was to use synthetics solely for industrial production. Such a position was reasonable given that the advent of synthetics for gem quality diamonds would substantially impact on gem prices and hence the value of De Beers' mined diamond assets. There has been no publicly stated change in that policy. However, the market for industrial diamonds, even more so than gem quality diamonds, is no longer under the control of any single producer. The fact that both the industrial and gem diamond market are far more competitive should result in greater uncertainty about the direction of future gem prices. This is especially so with the entry of many small synthetic diamond producers in China, which will, once they are more technologically proficient in the production of high quality synthetic gems, be able to produce gem quality diamonds at relatively low cost[6].

## 2.3 Acceptability of Mined and Synthetic Diamonds

Ultimately, the extent to which synthetic diamonds will grow to fill the emerging excess demand for gem quality stones and therefore replace mined diamonds, as was the experience with industrial diamonds, will depend on several market factors. These relate to the perception and understanding by consumers of the product being purchased. For the final consumer of diamond jewellery, the technical characteristics of the diamond itself are frequently a complete mystery. Views and beliefs about diamonds, as well as brand names, are for the consumer the results of advertising and perceptions transmitted by the media at a mesa level rather than any technical knowledge of the 4 Cs and their relationship to price of a specific product[7]. As diamonds are a product that is not frequently purchased, despite their expense consumers are often quite unaware of the quality of the product and are normally unwilling and unable to acquire the requisite knowledge to develop an informed view prior to purchase.

[6] 'China's market of synthetic diamonds is expanding', 31.03.2010, **Olga Patseva, Rough and Polished, Shanghai,** https://www.rough-polished.com/en/news/37804.html- November 2010. According to the statistics provided by the Association of Jewelry Industry of China, synthetic diamond production went up from 1.6 to 5.4 billion carats during the period of 2001 – 2009, increasing by approximately 16% per year. Experts believe that consumer demand for this production will go up by 16% annually in the nearest future. Forecasted demand for synthetic diamonds in 2012 amounts to 6 billion carats....Guo Liuxi being CEO of Huajing Diamonds – one of the largest synthetic diamond producers in China – pointed out that "notwithstanding the steady growth of diamond production in China and goods corresponding to the international standards, the country still falls short of high-quality synthetic diamonds. China's imports of synthetic diamonds exceeds exports by 2.4 – 7.2 times." Such difference, according to Guo Liuxi, is attributed to the fact that a huge gap exists between the Chinese and popular global diamond producers due to the weakness in terms of branding and average low quality of production, as well as insufficient use of advanced techniques of diamond production.' It is estimated that there were some 55 synthetic diamond producing firms in China in 2008.

[7] Diamonds are graded depending upon the 4Cs- cut, clarity, carat and color.

Branding has, as is the case with so many products, become an increasingly important tool for differentiation and perception of quality to occur and may well serve to protect the top end of the jewellery market for a period of time.

De Beers has, in many ways, become a victim of its own marketing success. The famous De Beers marketing cliché, 'diamonds are forever', created a growing demand for a product related to the belief that giving a diamond to a partner was a demonstration of love[8]. While the association of diamonds and love goes back at least to Greek mythology[9] its commercialization in the 20th century is very much a product of De Beers marketing effort. Giving of diamond rings emerged throughout the developed world as an almost necessary component of a marriage ritual (Bringig, 1990). The gift of a diamond ring is now becoming part of marriage rituals among higher income urban groups in both China and India[10]. However, it was the work of the De Beers extraordinarily successful marketing campaign in the US after World War II that linked diamonds with eternal love that has perpetuated the sentiment towards diamonds as opposed to any other gems as a symbol of love and affection and as the 'King of Gems,' despite the ever increasing volumes mined after World War II.

The problem that this successful post-war marketing campaign created for the diamond industry was that the reality of some, but by no means the majority, of the mining, cutting and marketing practices of the industry was very publicly at odds with any reasonable understanding of love. The high profile images of on-going human rights abuses associated with diamond mining[11], child labor in the Indian cutting industry[12], and most importantly the use of diamonds to fund conflicts in Africa[13], as well as allegedly in money laundering and funding terrorism[14], has adversely impacted the image of the mined diamonds as a symbol of eternal love. Many of the marketing outlets that are involved in the sale and distribution of the synthetics emphasize the absence of conflict, human rights abuses, along with a much smaller carbon footprint, are seen as important positive features of the marketing of synthetics[15].

In those parts of the world where such human rights and environmental considerations matter to buyers, this has undermined the reputation of mined diamonds and De Beers. Indeed, one of the reasons, but by no means the major one, cited by many researchers for the decline in the economic power of De Beers as a cartel in the 1990's was precisely the negative impact that its purchases of conflict diamonds had on the image and status of both the product and the firm. In many ways, this decline necessitated a complete corporate rebranding and the shift to the 'supplier of choice' business model of the company at the beginning of the current century.

### 2.4 Market Differentiation and Synthetic Diamonds- Pearls or Rubies and Emeralds?

A further and very important consideration in the question of the potential impact of synthetic gem quality diamonds on mined diamond prices and the reason that sections of the industry are concerned is the past

[8] The marketing slogan 'diamonds are forever' was extremely clever not just in its impact on the psychology of consumers, but in terms of the resulting economic consequences of the belief that a diamond was physically eternal, along with that of its market value. Diamonds are virtually indestructible and, hence, once, produced create a potential market overhang. This is similar to the case of other stores of value, such as gold. If these diamonds return to the market, this would destabilize the market and, by extension, any firm that is attempting to monopolize that market. Hence, the belief that the value of diamonds is forever and that these should be kept as symbols of eternal love that will, as a by-product, always appreciate in value becomes self-fulfilling so long as there is no return to the market of previous supply. In the words of Ball, a classic author on the Economics of the Gem Industry, 'At present the greatest "mine" of gems is that in the hands of the wealthy. Unlike secondary copper, "secondary" gems only return to the market following a complete economic upheaval. (Ball, 1935)

[9] See Spiegel D. , The *Mazzel* Ritual: Culture Customs and Crime in the Diamond Trade, Springer, New York, 2009 pages 42-44.

[10] There is only anecdotal and potentially biased evidence of the rising demand for engagement rings in China and India. 'Diamond demand soars in India'- June 2010 **'**About two decades ago, hardly any Chinese or Indian brides received diamond engagement rings. But, now nearly half of the couples getting married in these countries are buying them.' http://www.commodityonline.com/news/Diamond-demand-soars-in-India-29482-3-1.html Similar quotes attributed to Mr Gareth Penny, then Managing Director of De Beers suggest that this growth is, as one would expect, only in urban areas of India and China.

[11] Global Witness and Partnership Africa Canada, 2004, 'The Key to Kimberly Internal Diamond Control. Seven Case Studies; 'Return of the Blood Diamond; The Deadly Race to Control Zimbabwe's New Found Diamond Wealth, Global Witness, 2010, Dietrich, C. Hard, 2002, Currency: The Criminalized Diamond Economy of the DRC and its Neighbors,' Partnership Africa- Canada, IPIS. There have been repeated accusations of serious human rights abuses of workers in the diamond fields in Congo, Angola and Zimbabwe. Botswana has also been subjected to NGO criticisms because of the treatment of the San. For a refutation, see Solway., J., "Human Rights and NGO wrongs: Conflict Diamonds, Cultural wars and the "Bushman Question, *Africa*, 2009, Vol. 79, 321-346.

[12] Roberts, J., 'Glitter and Greed: The Secret World of the Diamond Empire', New York, The Disinformation Company Limited, See in particular Chapter 2, 'In Bondage- The Child and Adult Cutters in India.'

[13] Global Witness, Combating Conflict Diamonds, www.globalwitnes.org/pages/en/conflict_diamonds.html. There is an abundance of academic literature on the subject, including that on the Kimberly Process. See Siegel, D., The Mazzel Riutal: Culture Customs and Crime in the Diamond Trade, 2009, see pages 133-156.

[14] The use of diamonds as an instrument of money laundering and funding of terrorism is tightly controlled in the US under the terms of the Patriot Act. The reality of using diamonds as instruments of money laundering is critically analysed in Boles(2008).

[15] Both in the popular media, as well as in academic circles, the environmental and human rights benefits of synthetics are widely recognized; see for example 'Eric Franklin, 'Synthetic Diamonds', August 2010.' They (synthetic diamonds) are grown by scientists and only use a modest amount of electricity and resources, so do not share the environmental impact or "conflict" and labor issues sometimes associated with mined diamonds; http://www.pricescope.com/journal/synthetic-diamonds. See also Kelley(2008).

experience with the synthetic production of other precious gems and stones. The impact of synthetics ultimately rests on whether the two markets, synthetic and mined or natural products, can be adequately differentiated so as to assure that the price impact of increases in production in the synthetic market can be contained in that market. The history of precious stones and jewelry suggests that, wherever a valuable item exists, people will attempt to find ways to produce imitations. The experience of cultured pearls and synthetic emeralds and rubies are dramatically contrasting in terms of this vital issue of successful product differentiation between the synthetic and natural products. In the case of cultured pearls, the history of the industry shows that synthetic production resulted in the almost complete destruction of the natural pearl industry. This contrasts sharply to the case of both sapphires and rubies, where the mined and synthetic products continue to co-exist with quite separate markets. In the diamond industry, the optimists point to the case of emeralds and rubies and the pessimists about the effect of synthetics point to the case of pearls. The reason for why the market reacted so differently in the two cases is vital in determining which experience is more likely to be replicated in the diamond market in the current decade.

### 2.4.1 Rubies and Emeralds

The work of Viljoen[16] on precisely the question of the ability and cost of differentiating mined and synthetic products in terms of consumers and traders is important in understanding the diamond market and obtaining a reasoned analysis of whether mined diamond prices are sustainable in the longer term. Synthetic rubies, for example, were first produced in the 19th century as one of the first synthetic gems. At the beginning of the 20th century, Augusta Vermeil (after whom the synthetic rubies are named) succeeded to produce rubies and by 1907 had produced 5 million rubies. This caused a collapse of the market because of the loss of trust in the ruby trade (Ward,2003). However, once it was realized that synthetic rubies could be readily detected by X-ray and microscopic scrutiny, then mined ruby prices recovered after a very long slump[17]. Moreover, synthetic rubies scratch easily and have high level of impurities[18]. Thus, the synthetic product was both inferior to that of the mined product and also easily detectable. As a result, the condition needed to have one unified mined and sunthetic market did not readily exist because of the low transaction cost of detection. Synthetics continue to be used for industrial uses, but pose no threat to the mined gem quality ruby market. The extent to which prices are differentiated between the two was shown at a 2006 Christies auction, where an 8.62 carat ruby was sold for USD 3.6 million. At the same time, Vermeil sold at USD 6 per carat and flux grown rubies at USD 650 per carat (Kane, 2009). Large good quality synthetic rubies are high cost and dangerous to produce[19], taking many man hours and almost perfect natural rubies cost almost the same (Anderson, 1990).

**Table 1: Differences Between the Emerald, Ruby and Diamond Markets**

| | **Compared to Natural Production** | |
|---|---|---|
| **Artificial Production** | **Emerald and Rubies** | **Diamonds** |
| Cost of Production | Almost as Expensive | Much Cheaper |
| Ability to Identify | Easy and Inexpensive | Hard and Costly |
| Strength and Characteristics | Weaker Structure | Similar or Better |
| Production Time | Much longer | Shorter |
| Available Information | Widely Publicised | Very little Known |
| Reliability of Output Quality | Moderate | Very High |

**Source:** Viljoen, based on Webster, page 324, Anderson, page 101, Ward, pages 54-56 and Wickel.

Synthetic emeralds were first made by Carroll Chatham in the US in the 1940's but it was not until 1963 that they became fully commercialized in any quantity. They are produced with a mixture of minerals using a hydrothermal technique. However, these emeralds, which were clearly marketed as having been man-made or

[16] This section draws heavily upon parts of the analysis of Viljeon (2006).
[17] Webster, R., Gems, revised edition, Hmaden, conneticut, Archon Books
[18] http://jewelry.about.com/rubiessapphires/a/rubies.html
[19] Ward, F. op.cit. page 57.

'Chatham created', were easily distinguished from mined emeralds by X-ray techniques. These products are sold alongside mined emeralds at one tenth the price[20].

### 2.4.2 Pearls

The experience of the market acceptance of cultured pearls, as discussed above, is profoundly different from that of synthetic rubies and emeralds. The reason for this stems as much from the history of their market penetration as it does with the physical and price attributes of the two products. Cultured pearls have a longer history than that of most synthetic gems. The origins of pearls as natural gems stems from as far back as antiquity, when natural pearls were first harvested in both the Red Sea and the Arabian Gulf. Farmed production began in China in the 13th century, though its origins probably date back to before the common era (Taburiaux, 1985). The most important 20th century influence on the global pearl market was the patenting in 1908 by the Japanese merchant Kokoichi Mikimoto of his technique of pearl farming. By 1916, Mikimoto, now considered the father of modern pearl farming, had succeeded in making perfectly round pearls[21], which were considered superior to natural pearls. Round pearls have always been considered 'the ideal pearl' even prior to the development of cultured pearls. Thus, the first element in the explanation of why cultured pearls eventually came to displace natural pearls lay in the ability of pearls farmers to produce what nature only rarely produces, i.e., a perfectly round pearl[22].
However, it was what followed in the global pearl market in the 1920's and 1930's that was the principal and proximate cause of the decline of natural pearls[23]:

> The first modern influence on the European pearl market was from Japanese origin (sic) in 1922, and immediately caused fluctuations in the price and natural supply when it became known. These problems intensified with the 1929 Wall Street crash and subsequent global economic contraction, which caused the extraction of natural pearls to virtually cease for half a decade. The pearl shortage was filled with farmed pearls, which was easily able to continue production. Though these pearls were at first skeptically received by merchants due to their artificial origins, the product of the only viable source forced them to accept the goods.

**Table 2: Similarities between the Pearl and Diamonds Markets**

| | **Compared to Natural Production** | |
|---|---|---|
| **Artificial Production** | **Pearls** | **Diamonds** |
| Cost of Production | Low Due to Technology Use | Much Cheaper |
| Ability to Identify | Unreliable and Costly | Hard and Costly |
| Strength/Characteristics | Identical or Better | Similar or Better |
| Production Time | Shorter | Shorter |
| Available Information | Artificial Dominance Known | Very little Known |
| Reliability of Output Quality | Very High | Very High |
| Sustainable Production | Much longer | Much longer |
| Scale of Production | Similar, Can be Smaller | Much Smaller |
| Political Support Needed | Less | Much Less |
| Environmental Friendliness | Greater | Greater |

**Source:** Viljeon page 30 based on Taburiaux (2005) pp135-37, The Pearl Market 2005,

[20] See Viljeon, C., op.cit., page 28, Ward, op.cit, page 43.
[21] Ibid, page 137.
[22] The Pearl Market, History of the Pearl Market, 2005 on http://www.pearlmarket.com/peralhistory.
[23] Viljeon, op.cit., page 29.

The physical characteristics of cultured pearls compared to natural pearls means that while technical differentiation is possible, it is quite costly and has traditionally been found to be unreliable. As table 2 above indicates, these characteristics are in many ways very similar to that of synthetic diamonds. Both pearls and synthetic diamonds can be produced at lower cost with superior physical qualities than their natural counterpart. Perhaps the most significant factor that explains the long term decline of natural pearls has been the deterioration in natural supply of pearls stemming from the progressive deterioration of the coral reefs that have been continually over-exploited for fishing purposes. It is this factor, the decline of natural supply that is most similar to the situation that is currently emerging in the global diamond market. While synthetic diamonds may still prove to be differentiated from their natural counterparts in the global diamond market, the experience of the pearl market with its limited supply of natural products, the superiority of synthetics and the difficulty of detection suggest that there are strong similarities between the two and hence good reason for diamantaire to be concerned.

### 2.5 The New Diamond Age and the Blurring of the Industrial/Gem Distinction

Traditionally, industrial diamonds have been the detritus of the diamond mining industry- goods considered to be of such inferior quality that they could not be used as gems. However, with the development of what are now low cost and very high quality synthetics and their application to new high technology products, well beyond the traditional coating and cutting qualities, the technical and quality distinction between industrial and gem quality diamonds is fast disappearing. Diamonds have numerous scientific and technical qualities that make their industrial application useful well beyond the traditional uses. These stem from the inherent hardness and durability of diamonds[24]. The early industrial applications of diamonds stemmed not from a full use of the very wide and exceptional qualities of diamonds which were well known to scientists, but that mined diamonds and synthetic diamonds produced by earlier technologies meant that prices along with their size, shape, clarity and level of impurity limited the potential range of high technology applications.

CVD diamonds, like their mined counterparts, have the same physical properties including ultra-high thermal conductivity, optical transparency and a very high elastic modulus and hardness as their natural counterparts, but can be manufactured at a fraction of the cost of mined diamonds and provide a steady supply that cannot be assured from mining. As a result of these qualities CVD diamonds, unlike previous synthetic applications, can be readily produced in sheets that can be applied in micro-mechanical and opto-mechanical heat spreaders, laser windows, as well as other civil applications (Fabiask and Staryga, 2009). Diamonds also potentially have very important military applications which stem from the hardness of the material[25]. The particular qualities of diamond create further possibilities for application in medicine in nanotechnology for in-body sensors (Linaries *et al*, 2009). The many potential uses of what would certainly have to be relatively low cost diamonds alters completely the traditional perception of industrial diamonds as the detritus of the industry. The pressure to find low cost manufacturing techniques will be driven by technology, and this will have a major spillover into the gem quality market. However, as we shall see, it is the technical quality of the CVD diamonds, namely that, they cannot be distiguished by a diamantaire from mined diamonds without scientific equipment (Song, 2007). This means that CVD diamonds pose a particular challenge to the gem market that were previously not found in other synthetics and simulants[26] that had been developed throughout the 20$^{th}$ century.

It is the De Beers subsidiary, Element 6, which was responsible in 1990's for the development of many new industrial uses for CVD diamonds including in electronics, surgical scalpels, optical windows and in telecommunications equipment. Perhaps the single most important development made by Element 6 was the development of a way to fuse diamond grit with solvent to produce a very cheap coating substance. De Beers has been at forefront of industrial diamond research for at least three decades, but the diffusion of the technology to many countries and companies has been very rapid and no similarly dominant position to that which existed in the mined gem quality diamond market can be assumed.

[24] For a full description of the scientific and technical qualities of diamonds, see May (2000).
[25] The US Naval Research Laboratory as well as the Soviet Military had over many years provided considerable resources for research into the potential military applications of diamonds.
[26] Diamond *simulants* have been on the market for many years, but do not have the same chemical, physical and optical properties as a diamond. These include cubic zirconium, moissanite and diamond coated CZ.

Perhaps the most important development has not simply been the new technology, but the reported decrease in production costs. Cost of production data, in the diamond industry which is normally highly secretive, is very scarce and little beyond anecdotal evidence exists. One of the pre eminent scholars in the area could conclude that production costs for CVD diamonds 'fell below $1(per carat) for the first time in the year 2000'[27]. While this was still high given the competing materials in many industrial end uses, the research programs driven by industrial, military and research uses will almost certainly result in even lower prices. The importance of the cost decline of CVD diamonds, which began in earnest in the current century, has meant that many of the previously sub-economic industrial and high technology applications of diamonds are now increasingly financially viable. The United States Geological Survey has also reported that when Apollo diamonds are fully developed they will be produced for as little as USD 5 per carat[28]. It is not possible to speak of one cost or price estimate for CVD diamonds as it will vary with quality, end use and the producer and technology involved.

The production of single crystal diamonds in sheets has meant that the use of diamonds is no longer limited to what could be produced either by nature or through the HPHT method and has meant that an entirely new series of technical possibilities have emerged. However, whether the application of diamonds in computer chips, as a replacement of silicon because of the superior heat conducting properties, ever becomes a widespread application depends upon the rate of cost decrease and the technological changes occurring with other competing materials. It remains a possibility that other synthetic materials currently being developed using nanotechnology will mean that diamonds will never receive widespread application in the computer or other industries that researchers, commercial proponents and developers envisage. Conversely, the rate of cost decrease of both CVD and HPHT diamonds and their application with a combination of other materials may yet create a very large modern industrial market of unknown proportions.

Many of the technical barriers limiting the size and clarity of diamonds have already been broken down; and in 2010, the GIA had graded its first CVD diamond at over one carat[29]. Significantly, research by the Carnegie Institute has developed new annealing techniques that create potential for extremely low cost, high carat CVD diamonds without the need for high cost HPHT annealing. The research has resulted in 'brown CVD diamonds transformed by this cost-efficient method into clear, pink-tinted crystals..... The most exciting aspect of this new annealing process is the unlimited size of the crystals that can be treated. The breakthrough will allow us to push to kilo carat diamonds of high optical quality'[30]. These are, of course, laboratory results and cannot necessarily be seen as developments that will be commercialized in the immediate future. However, the complex range of technical constraints to the production of high volume, high quality and, most significantly, low cost synthetics is being gradually eroded; and, therefore, it would be imprudent for mined diamond producers and the jewellery industry to presume that the 'King of Gems' will not be dethroned as was the case temporarily last in the 19th century with the discovery of the Kimberly mines in South Africa and the flooding of the London market, which resulted in sapphire prices being above that of diamonds.

What also needs to be understood is that the synthetic production and enhancement of gem quality diamonds has become very much part of the mainstream of the mined diamond industry. What further blurs the distinction between mined and synthetic diamonds is the process of diamond enhancement. Indeed, the HPHT technologies that have been used generally to produce industrial diamonds have long been used to enhance the coluor and clarity of inferior gem quality diamonds (Overtan *et al*, 2008). Even long before the advent of annealing processes to enhance diamonds, diamantaires have used these enhancement techniques to improve the coluor and optical qualities of gem quality diamonds. This process further blurs the distinction between natural and synthetic diamonds and many of the enhancement techniques are extremely difficult to detect.

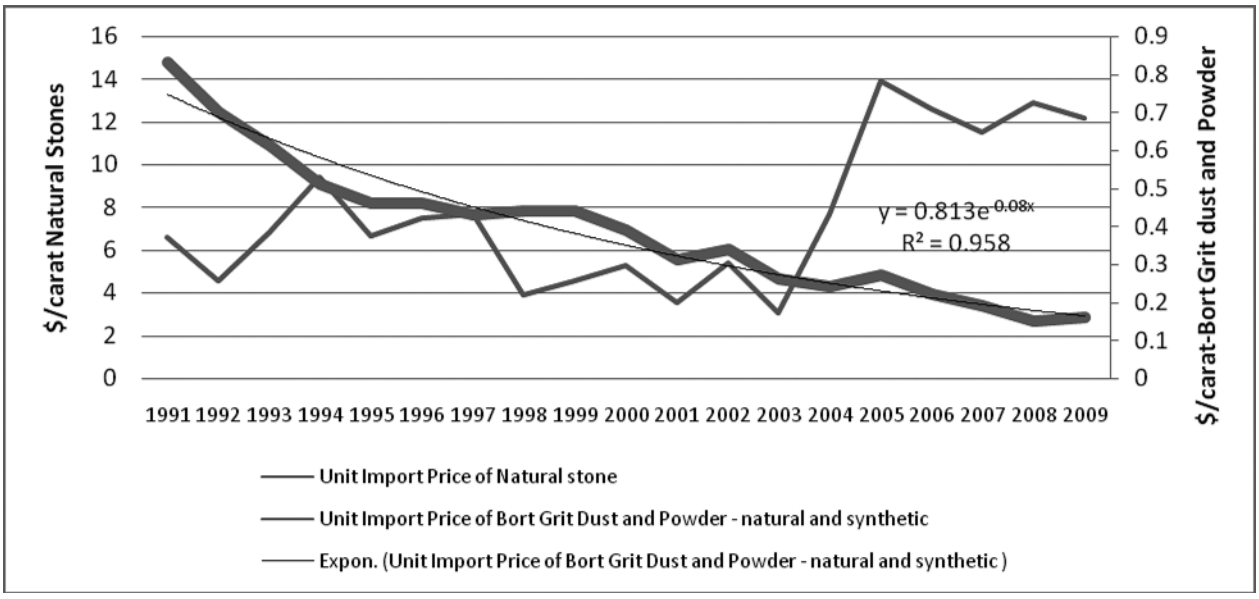
[27] P.W. May, op. cit., page 487.
[28] Olson D., USGS, op. cit., 2005, page 224.
[29] 'Lab Identifies First CVD Synthetic Diamond Over One Carat' May 5, 2010 http://www.diamondne.ws/2010/05/05/lab-identifies-first-cvd-synthetic-diamond-over-one-carat/
[30] Catherine Brahic 'Artificial diamonds - now available in extra large' *New Scientist* 13 November 2008; http://www.newscientist.com/article/dn16036-artificial-diamonds--now-available-in-extra-large.html see also Yu-fei Meng et al (2008).

The response of mined diamond producers and those further down-stream should be to attempt to differentiate their product from synthetics, but the last 20-30 years of diamond industry development has made this a serious challenge, as the lines between natural and synthetic and industrial and gem quality products vanish over time.

### 2.6 Synthetics and the Collapse of Industrial Diamond Prices

The experience that is perhaps the closest to 'the worst case scenario' for mined gem quality diamonds is what has happened to the market for industrial diamonds over the last half century since the development and marketing of synthetics in significant quantities. Traditionally, the diamond market has been divided into three components, industrial diamonds, gem quality and investment diamonds (Ariovich, 1985). Each segment of the market has very different economics and price is determined by quite different factors in the case of each. If there is a logical economic delineation between the gem and industrial segments of the market, it is that industrial diamonds are not, as the marketing cliché suggests, 'forever'; and, indeed, the opposite is the case, as 96% of mined industrial diamonds entering the market in any given year are used up in industrial processes (Maillard, 1980). Gem quality diamonds, on the other hand, never disappear from the market, but overhang it and only rarely re-enter the secondary market in any significant quantity. It is only in the most extreme of circumstances, e.g., after the Bolshevik revolution in 1918, the Great Depression, etc., that diamonds return to the market for sale in any significant quantity. It is also the very reason why synthetic diamonds pose such a unique challenge to the stability of the gem quality market.

**Fig. 5: US Unit Import Prices of Bort, Grit, Dust and Powder and Natural Stones for Industrial Uses**




**Source:** US Geological Survey

The traditional industrial diamond market is further divided into stones and borts, grits and powders. Though first invented at the beginning of the 20th century, the technological application of synthetic diamonds as a commercial product has a history stemming back to the 1950's when the first diamonds were produced in Sweden[31]. Synthetic diamonds were only first sold in the US in statistically significant commercial quantities[32] in 1958, but by 1978 they had overtaken mined diamonds on the global industrial market[33]. Since the development of HPHT diamonds in the 1950s, the industrial segment market has become dominated by synthetics.

However, by 2008, according to USGS data, some 98.5% of global industrial diamond market was supplied by synthetics, with the vast majority being produced in China (86%) which produces over 4 billion carats per

[31] An independent diamond synthesis was first achieved on February 16, 1953 in by the Allmänna Svenska Elektriska Aktiebolaget, (ASEA), one of Sweden's major electrical manufacturing companies. See (Hazen 1999). The following year General Electric synthetised a diamond, which was not of gem quality, It was not until 1970 that Sumitomo started to market gem quality diamonds.
[32] See US Geological Survey web site http://minerals.usgs.gov/minerals/pubs/commodity/diamond/archive
33 See Element 6, http://www.e6.com/en/education/thesecretlifeofindustrialdiamond/

annum. More significantly, by 2008 industrial diamond prices in the US, according to the USGS, were, on average, approximately USD 0.23/carat[34].

Market prices for industrial diamonds and their long term behavior vary greatly between natural stones and that of borts, grit and powder, which are now almost entirely synthetic. Natural industrial diamond prices tend to be influenced by both the supply of synthetic substitutes and the price of gem quality diamonds. Prior to the surge in synthetic production, industrial diamond unit values in the US averaged USD 5/carat in 1980/81. By 2008, prices had fallen to USD 0.23 per carat. This precipitous decline in price stems not from a decrease in demand for industrial diamonds; indeed the opposite is the case, but rather from two substantial waves of increased supply of synthetics to the global industrial diamond market. The first wave occurred in the 1970's and 1980's, when estimated global production increased from approximately 6 tonnes per annum in 1980 to over 76 tonnes of industrial diamonds by 1988. Though world production increased slightly in the 1990's to over 100 tonnes per annum, prices continued to decline. In what was a statistical error of gargantuan proportions, the US Geological Survey in 2005 could still claim that the US was the 'largest producer and consumer of industrial diamonds' (Olson, 2005). In reality, and apparently unbeknownst to the USGS, the Chinese had overtaken the US in the early part of the decade. Thus, a technological change, which had only been initially commercialized in 1958, had, in effect, eclipsed the market for mined diamonds for industrial purposes within a period of 50 years.

It was not until 2004 that we see a further quantum increase, when global industrial diamond production which increased from approximately 113 tonnes in 2001 to an estimated 900 tonnes after 2004. This was, in large measure, as a result of the entry of Chinese production onto the global industrial diamond market, in particular for abrasives. China, as part of its emerging role as an industrial giant, and part of the tectonic shift in global economic power, has become the world's largest producer of diamonds by volume. Based on recently published estimates by Zihong *et al*, 2009[35], China, with almost no mined production, yet produces approximately 80% of total global production of diamonds by volume[36].

The secular decline of world prices of industrial diamonds over the last three decades was as a result of the production on an industrial scale of largely HPHT diamonds starting in the 1960's and is the background to the current study. A second wave of technological change has now occurred and a new and potentially much lower cost method of production synthetics is now available. CVD diamonds, unlike HPHT, are produced at lower temperature and as a result, potentially at much lower costs of production[37]. Consequently, these diamonds open up possibilities for industrial uses that were previously considered to be economically impractical. The growth in demand is likely to be experienced as a result of new varieties of manufactured diamonds and their application beyond the traditional industrial use as coating and cutting materials and will mean that the definition of an industrial diamond will greatly expand over time.

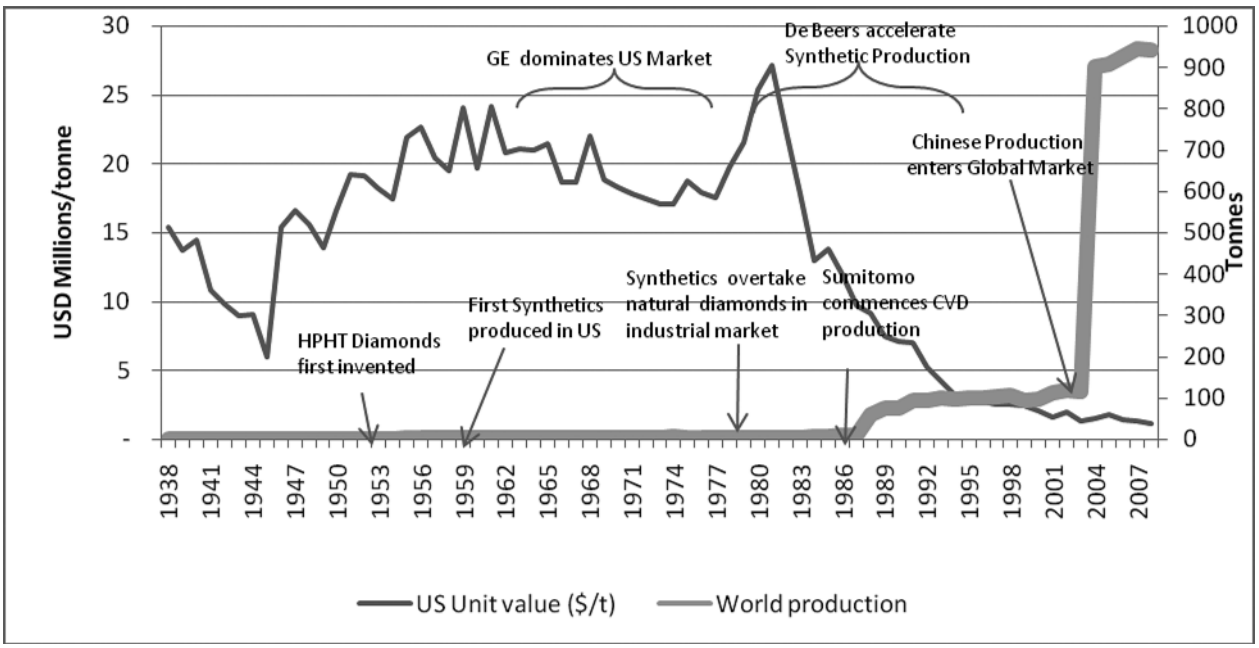
[34] The US Geological Survey data states that unit price of industrial diamonds is USD 1,180,000 per tonne in 2008 or USD 0.23 per carat. There are clearly inconsistencies between the data gathered by USGS and observed market prices of industrial diamonds. Olson writes, 'In general, synthetic diamond prices for grinding and polishing range from as low as $0.40 to $2.00 per carat. Strong and blocky material for sawing and drilling sells for $2.50 to $3.50 per carat. Large synthetic crystals with excellent structure for specific applications sell for many hundreds of dollars per carat'. US Geological Survey Mineral Year Book, 2008. http://minerals.usgs.gov/minerals/pubs/commodity/diamond/mcs-2008-diamo.pdf.

[35] 'In 2007, China produced nearly 4.4 billion carats, 80% of the world's total diamond output....59% of US imported diamonds were from China; in Japan, 40%'.

[36] It is testimony to the secrecy of the diamond industry that, in 2005, the USGS, the most authoritative source for statistics on industrial diamonds could claim in its mineral yearbook that China was only producing 17,000,000 carats in 2004. The following year the USGS upgraded its statistical estimates of Chinese production to over 4 billion carats for 2004.

[37] Under the HPHT method pure carbon is put under pressures of 50,000 atmospheres and temperatures between 1100 and 1400 degrees Celsius and will therefore reproduce the environment that creates diamonds inside the earth's core.

**Fig. 6: US Unit Prices and Global Production of Industrial Diamonds (1938-2008)**




**Source:** US Geological Survey, Element 6, Phaal et.al NB Unit value determined by USGS is the value in dollars of 1 metric ton (t) of natural and synthetic diamond apparent consumption. Unit value data were estimated as being equal to the total value of imports divided by the total import quantity.

The chart above depicts the US unit import values of industrial diamonds over the last 70 years. Until the late 1950's when industrial diamonds began to be produced, synthetically, prices like that of gem quality natural diamonds, continued to increase. However, once synthetics became serious competitors for mined industrial diamonds, prices started to decline, at first slowly and with some respite in the 1970's, until 1980, with the commodity booms of that period. However, following the 1978 'tipping point' when synthetics became a greater share of world industrial diamond demand, and in the 1980's, with the acceleration of synthetic production efforts by De Beers, prices began a near perfect exponential decline. By 2008, nominal industrial diamond prices in the US were 4.6% of the 1981 peak. It should, of course, be noted that these import prices are not necessarily representative of the price of industrial diamonds, as high value production of synthetics occurs in the US and will not be captured in the trade data. The question is whether there exists any reasonable possibility that gem quality synthetics will be able to have the same effect on the price of mined gem quality diamonds as was the case of industrial synthetics? If this is the case, how long will the process take?

### 3. The Impact of Synthetic Diamonds on Prices and the Botswana and the SADC Economy

It does not require significant analysis to realize that Botswana, the world's most diamond export dependent country, is simultaneously the most vulnerable to any supply shock stemming from synthetics because it has the least diversified economy of all diamond producing countries. The table below outlines the extent of dependence on exports of all the SADC countries on diamonds. Synthetics should be of concern to Botswana, Lesotho and Namibia. For Botswana, a precipitous long term decline in price will have a greater impact on the economy than for any other producer.

**Table 3: Diamonds as a Percentage of Total Commodity Exports**

| | *2010* | *2011* |
|---|---|---|
| *Angola* | *1.2%* | *1.7%* |
| *Botswana* | *68.5%* | *75.6%* |
| *Democratic Republic of Congo* | *3.2%* | *2.9%* |
| *Lesotho* | *21.0%* | *22.7%* |
| *Namibia* | *17.6%* | *18.4%* |
| *South Africa* | *0.9%* | *1.4%* |
| *Tanzania* | *0.33%* | *0.2%* |
| *Zimbabwe* | *10.0%* | *12.0%* |

**Source:** Kimberly Process, International Monetary Fund

Diamond exports constitute between 30-50% of the government's total revenue through taxes, royalties and dividends paid by Debswana and De Beers. The purpose of the discussion below is to consider the impact of declining prices on government mining tax revenues and general revenues. While the Government of Botswana earns significant revenues directly from the taxation of diamond mining, any decline in prices will not only effect mineral taxation but also returns on investment in the diamond sector. These will be compounded by the fact that declining prices of diamonds will also affect Botswana through the revenues the company derives from share ownership of Debswana and De Beers.

In the absence of monopolistic or legal, i.e., patent constraints to the contrary, synthetic diamond prices will, like all industrial commodities, ultimately decrease towards the marginal cost of production. The degree to which a cleavage, albeit temporary, between virtually identical mined and synthetic prices can be maintained rests ultimately on the capacity of mined diamond producers to be able to differentiate their products from synthetics in the minds of consumers. While such a long term differentiation remains possible, most of the efforts in the industry thus far have been to assist intermediaries and jewellers differentiate the product and the consumer remaining dangerously unaware of synthetics.

The evidence that is publicly available suggests that synthetic diamonds can be produced at a fraction of the cost of extracting mined diamonds[38]. Botswana is one of the lowest cost producers of mined diamonds in the world, and while it may survive a sustained penetration by synthetics, the expected price decreases would mean that government revenues would certainly decline dramatically. There is no reason to believe that any price decline of gem quality mined diamonds will follow the pattern established by industrial diamonds where a relatively smooth long term decline in prices is observed. The reason for expecting a quite different price decay is because:

**i)** During the advent of synthetic industrial diamonds, in the 1950s and 1960s, the technology for the production was disbursed amongst a very small number of producers in advanced developed countries in Europe and the USA. This is no longer the case, as the entry of China on an unprecedented scale into the industrial diamond market post-2004 demonstrates. There has been enormous progress in synthetic diamond technology in the last 50 years and gem quality CVD diamonds are now being produced in several countries, including China.

[38] In February 2009, then Managing Director of De Beers, Gareth Penny is quoted as saying 'we have got 43 synthetic machines down the road that are capable of producing the equivalent of Jwaneng's entire annual output of 1 carat diamonds at a fraction of the cost. If consumers just wanted crystallized carbon then you wouldn't bother mining it, you would manufacture it…' in Audrey Lute, 7th July 2010, 'Can De Beers Entre Synthetic Diamond Market? http://www.gazettebw.com/index.php?=view&catid=18%3Aheadline&id=6901%3

**ii)** The relative price of mined to synthetic gem quality diamonds[39] suggests that for the moment there are considerable rents being earned by synthetic diamond producers, which will, in turn, invite further entry. Economic rents in the gem quality market have always been much larger than in the industrial diamond market. Moreover, the rents in the diamond industry lie at two points in the value chain, first in the mining sector and second, at the jewellery end of the market. The middle of the diamond value chains tends to be far more competitive and less profitable. As a result of the rents, entry into the gem market by synthetic manufacturers is likely to be far more rapid than was the case with industrial diamonds, and the slope of the price decay function will probably be far steeper than that depicted below for industrial diamonds.

**iii)** Economic theory also predicts that, in the absence of adequate and enforceable standards and labeling, synthetics, especially in a market where the transaction costs of detection are high, will enter the mined diamond jewellery market through fraudulent means. As will be discussed in the following section, there is mounting evidence that this is already occurring.

**iv)** The shortages of mined diamonds widely predicted by the mined diamond industry, is similar to the case of cultured pearls and in the absence of any dominant player in the market, suggests that entry will be rapid once production expands to meet the emerging shortages.

What is not possible to calculate or predict is whether there will be a sudden and precipitous decline in gem prices stemming from a fundamental change in consumer perception and sentiment regarding the long term value of diamonds as a store of value. For a good to be a store of value, its price must rise faster than the rate of inflation plus the real rate of interest, i.e., the carrying cost. This was largely assured in the past by De Beers, but since the demise of the cartel arrangement, this rate of price increase cannot be assured. However, the experience of the decrease in diamond production in the 'De Beers Zone' ( Botswana, Canada, Namibia and South Africa) in the wake of the economic crisis suggests that price increases can be maintained if production levels are contained in these countries.

The diamond industry, at least publicly, claims that it has no data on the extent to which synthetics have already entered the value chain as most diamonds were not tested in the past and certificates in the US market were only granted by organizations such as the GIA post-2007. As the understanding amongst key consumers of the extent of synthetic diamond penetration of the jewellery market increases, the fundamental factor which underlay the market in the past, i.e., the knowledge/faith and trust that diamond prices will rise on a regular basis may be eroded and consumer confidence in diamonds as a store of value could disappear. If this were to eventuate, diamonds, that were previously stored or not sold, may re-enter the secondary market, which would significantly lower prices.

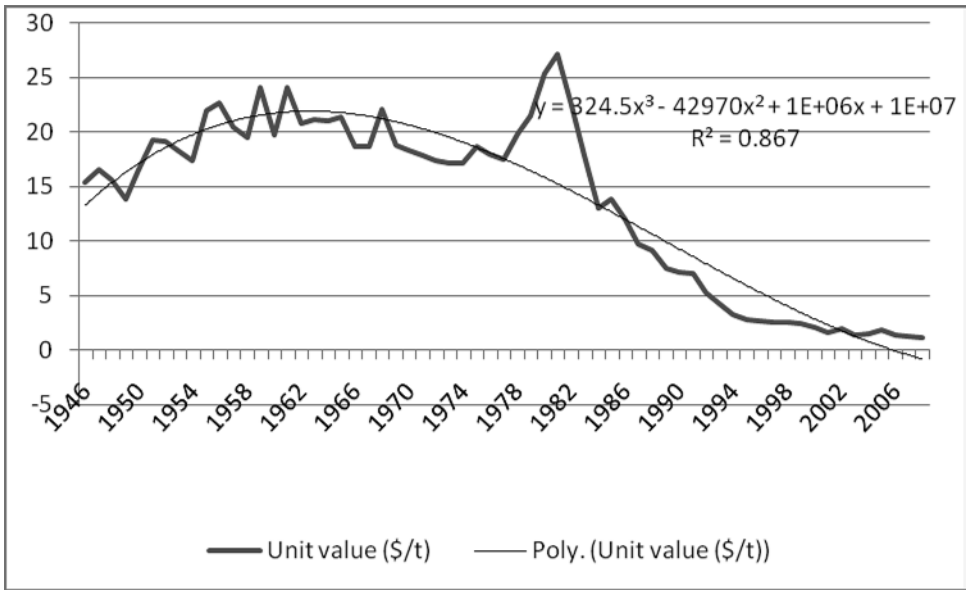
### 3.1 Impact on Botswana's Mining Tax Revenue

The unit value decay function below shows the change in prices for industrial diamonds over a 60 year period. Prices fell from their peak of USD 24 million/tonne in 1958 at the beginning of the synthetic entry into the industrial market to slightly over USD 1.18 million in 2008, a decline of 6.5% per annum over the period. However, this fact alone cannot be a useful guide to current policy in Botswana in the gem sector. The history of the industrial diamond industry is profoundly different to that of gem quality diamonds and the price decay function of industrial diamonds has gone through three phases in the post-war period. The first phase of the industry corresponds to the period from the end of the World War II to 1958/9, when synthetics had not yet entered the industrial market; and this is a period typified by rising nominal and real prices for industrial diamonds in the US market.

[39] O'Connell, writing in the Wall Street Journal, 13th January 2007, estimated that natural colorless diamonds were available at retail level at USD 900-2,500 for a half carat. At that time, no one carat CVD diamonds were available. A one carat colourless mined diamond was selling at USD 6,800-9,100. There are clear asymmetries in the price formation of half and one carat diamonds and they are not strictly comparable. Discounts of 30% off the price of mined diamonds were reported in the press in 2007-2008 period. However, discounts on colored diamonds produced by HPHT methods were reportedly far larger. A one carat pink natural diamond could retail for USD 100,000 compared to USD 4,000 for a one carat HPHT pink diamond. The average differential estimated between synthetic and natural diamonds was estimated to be 15% by O'Connell at the time of writing in 2007. http://online.wsj.com/article_print/SB116847789509758 02.html

Almost immediately from the 1960's until the early 1980's, a period of price stagnation occurred when synthetics rapidly entered the market and became dominant source of supply after 1978. By this time, industrial diamonds became, in effect, an industrial commodity that could be supplied through manufacturing processes. The final period following the Iranian revolution price hikes for all commodities that saw industrial diamond prices rise and then go through a period of exponential decline which does not yet appear to have come to an end. Perhaps the most important observation from the perspective of the gem market is that, while a modest nominal decline in industrial diamond unit values occurred at the beginning of the synthetic life cycle in the late 1950's and early 1960's, it was not until the post-1978, when synthetics began to dominate the industrial diamond market, that the exponential decline in nominal prices is observed in the polynomial decay function below.

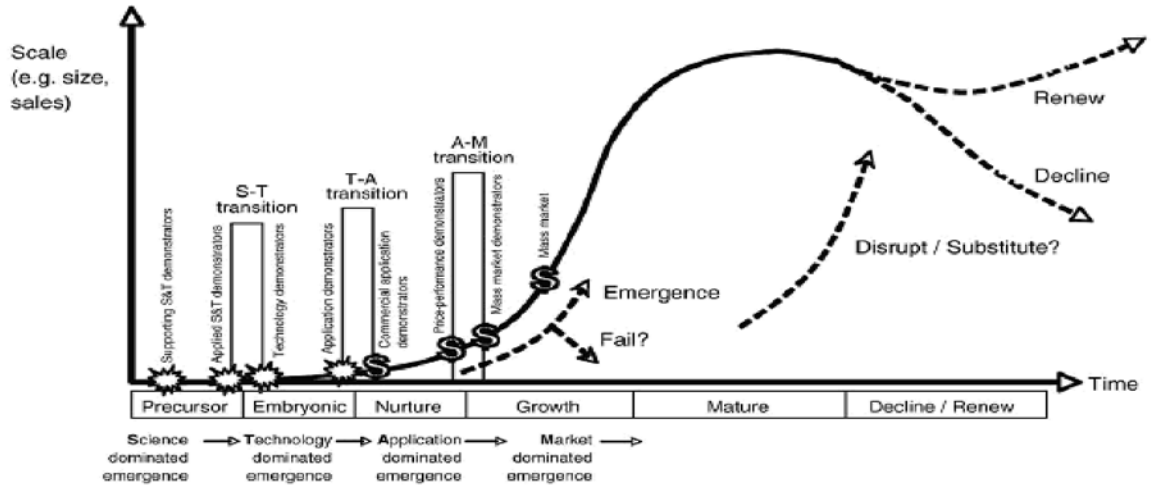
**Fig. 7: Unit Import Value of Industrial Diamonds in the US (USD millions/tonne)**




**Source:** USGS

What becomes clear is that the decay of unit import values for industrial diamonds follows almost identically the stylized product life cycle of industrial diamonds depicted below. Phaal's (2010) argument is that the industrial diamond market was, at the time of writing, at a stage of either decline or renewal in its traditional uses (Phaal, 2010). Whether there will be a renewal stage of industrial diamonds will depend upon the new end uses that will be found for industrial diamonds in the coming years. This scientific research is on-going and whether industrial diamonds develop as an industrial material on the scale imagined by its many proponents will depend on the application of the scientific research and the commercial considerations regarding its costs relative to other competing synthetic and hybrid materials. However, the obvious point is that the renewal of industrial diamonds depends crucially on the resolution of the technical constraints to increased size and quality of CVD diamonds at lower cost. It is precisely these qualities that are sought in the gem sector and, hence, this renewal of industrial synthetics that will, unless the two markets can be clearly differentiated, accelerate the decay of mined gem diamond prices.

**Fig. 8: Product Life Cycle - Industrial Synthetic Diamond**




**Source:** Paal op. cit, p8

A decline in gem quality diamond prices would decrease Botswana government mining tax revenues. In the estimations undertaken it was found that a 1% decrease in unit export value of diamonds results in a 0.91% decrease in mineral tax revenue[40]. The precise impact of synthetics on the revenue of Botswana will depend almost entirely on the acceptability of synthetics and their penetration of the gem market. The possibility a sharp shock to the diamond market coming from the increased use of synthetics cannot be discounted because it may be associated with a loss on consumer confidence in diamond as a store of value. The estimates are based on tax revenue only, and do not measure the impact of any decrease in diamond prices on total revenues because the impact extends both through its impact on Debswana, as well as Botswana's holdings of De Beers shares and through the entire macro economy[41].

The question arises as to precisely where in the life cycle of synthetic gem diamonds is the industry presently located. At this stage of the development, synthetic gem quality diamonds can still be characterised as in the 'nurture stage' with an expected growth stage lying ahead. Even with a relatively slow acceptance of synthetics in the global market, the time frame is such that it could dramatically affect Botswana government revenues. As the chart above shows, once unit import prices for industrial diamonds began their decline after 1980, when industrial diamonds came to dominate supply, prices declined by 50% within a decade. The ramifications of such a decline in the price of gem quality diamonds for the government revenue in Botswana would be far more serious.

What remains unknowable is the impact that synthetics will have on the perception of consumers and investors regarding the long term value of diamonds as a store of value. At present consumers remain barely cognizant of the existence of synthetics and it is entirely plausible that the industry, fearing the impact on the short term profits, will not devote sufficient attention and resources to this issue. A precipitous decline in diamond price is entirely possible as consumers become aware that industry practices such as synthetic enhancement and annealment of mined diamonds, which are discussed below, blur the distinction between mined and synthetic diamonds and undermine their long term value.

## 4. Response of Stakeholders to the Challenge of Synthetics

This section considers the response of at least four groups of stakeholders who have been developing strategies that either directly or indirectly increase their ability to manage the challenges created by the entry of synthetics

[40] While the common figure assumed to be embedded in the GRB-De Beers agreement is that 82% of revenue accrues to the state is lower than the elasticity measure this may be a result of the impact that a price increase has upon profits and hence government revenue. It could also be explained as being a result of the fact that unit export values are a highly imperfect proxy of price.

[41] The Government of Botswana holds 50% of shares in Debswana with De Beers, but also owns 15% of the De Beers Group.

into the gem segment of the diamond market.

While some of the strategies described below, such as branding, are there to address various market concerns of the actors, and are not meant to directly or immediately address the threat of synthetics they nonetheless do so as a consequence of the differentiation created and the standards of the brand owner. Other responses are more directly a result of the synthetics, such as the policy of the Government of Botswana, as well as the regulatory authorities in the US and the EU. Defending the value of mined diamonds against the consequence that the introduction of synthetics into the value chain is based on what the industry refers to as 4D's-differentiation, detection, disclosure and documentation. We shall see that while De Beers has invested havily in differentiation and detection: disclosure and documentation remained the purview of the jewellery industry and the standard setting bodies. However, as we shall see, because differentiation and detection remain essentially voluntery efforts, with considerable rents earned by those involved in a nefarious-arbitrage between the two, the attempts at managing the entry of synthetics into the diamond value chain has been weak. It is only following the first major crisis caused by nefarious penetration that standards are likely to move from being voluntery to mandatory.

### 4.1 De Beers From Differentiation to Rebranding and Franchising

In considering the corporate response of De Beers to the threat posed by synthetics to its core commercial interests in mining, which has been the most profitable part of the diamond value chain, three discernible stages are evident. The first stage, centres is around the Gem Defense Program of the 1990's, which was a purely defensive response, as it attempted to differentiate the synthetic from natural markets on a purely technical basis. The second stage, which begins with supplier of choice strategy in 2000, results from a broader repositioning and rebranding of the De Beers Group and is adaptive in nature. The final stage is the acceptance of the reality of diminished natural supply of diamonds and rise of synthetics, which will almost certainly see De Beers becoming a major producer of synthetic gem quality diamonds.

Early in its response to the threat posed by synthetic diamonds and their penetration of the gem market, De Beers established a Gem Defense Programme[42] and provided firms with equipment that would allow them to differentiate synthetics from natural stones[43]. In the 1990's De Beers developed two instruments that can differentiate synthetics from mined diamonds. DiamondSure is a relatively low cost instrument (USD 23,000 in the EU) examining light absorption, but does produce ambiguous results[44] and without the second much more expensive instrument, DiamondView (USD 40,000 in the EU)[45], which examines the reaction to fluorescent light but has a very high cost which makes it more difficult for jewellers to acquire. These were meant to overcome the constraint posed by the fact that synthetics and mined diamonds are, as mentioned above indistinguishable to the naked eye, even by a trained diamantaire.

De Beers has also moved to introduce branding of its products. Under its post-2000 Supplier of Choice strategy. It has placed its 'Forevermark' brand on stones for selected customers[46]. De Beers' decision to reposition itself at the beginning of the last decade through its 'Supplier of Choice' strategy was an attempt to move up the value chain to the retailing of top-end diamonds, which, after mining, is the most profitable part of the value chain. A second 'De Beers' brand was also to be used in its marketing arrangement with Louis Vuiton-Moet Henessy. The objective of the branding strategy cannot be said to be primarily motivated by an attempt to insulate itself from the consequence of synthetics, but rather to deal with the threat to its corporate reputation and a need to reposition itself as the global diamond market changed after the various shocks of the 1990's. However, by so doing, De Beers has also achieved the subsidiary objective of protecting its product from synthetics.

[42] Gem Defence Program was established by DTC – see Viljeon op cit., pp.59-61

[43] De Beers developed, but did not directly market two instruments, to distinguish synthetic diamonds from natural diamonds. The Diamond Sure™ and The Diamond View™ diamond is natural or synthetic. See Christopher M. Welbourn et al., 'De Beers Natural versus Synthetic Diamond Verification Instrument', *Gems and Gemology*, Volume 32, No 3, 1996 pp 156-169.

[44] 'Approximately 2% of diamonds such as Type II and Type IaB, are referred for further testing along with all simulants and synthetics' http://www.giainstruments.co.uk/index.cfm, accessed January 2011.

[45] See 'DTC Appoints GIA Distributor of Diamond Sure and Diamond View', http://www.professionaljeweler.com/archives/news/2004/041904story.html

[46] It should be noted that this form of branding is very new and follows a long period of research. Moreover branding is not automatic. Sight holders have to return the polished stone and request the 'Forever mark' be placed on the polished diamond.

While De Beers has moved to brand its diamond product, as well as produce machinery for the detection of synthetics, it has also moved on a second and perhaps more important track for the future of its diamond operations and the industry as a whole. It has continued to advance its own research towards the development of synthetic diamonds and annealing processes, which enhance both natural and synthetic diamonds. In December 2010, Element 6 was issued patents on enhancement processes to produce fancy orange colored synthetics diamonds that 'maybe used as gemstones' (Ever-Zohar, 2011). De Beers had long held that its research on synthetics was either for industrial purposes or to help develop improved detection instruments for the gem trade. However, it also held that, should market conditions make this necessary, it would enter the synthetic gem quality market. De Beers is faced with a delicate balancing of its commercial interests. It can either remain out of the synthetic gem market, thereby allowing the emerging excess demand for diamonds to be filled by other producers, or enter the synthetic gem industry and run the risk of potentially diminishing the value of its global diamond mine assets. There can be little doubt that De Beers will have no choice, but to evolve into a major synthetic gem supplier. Whereas in the past, De Beers' technical superiority in the area of synthetics could assure the company an element of market control in this area, the diffusion of the CVD and annealing technologies to many firms and countries means that it will not be in a position to dominate the synthetic gem market for long.

### 4.2 The Jewellery Industry - Branding and Voluntary Codes

At the beginning of the millennium, with the seismic shift in the nature of the gem diamond market that was associated with De Beers' abrogation of its cartel position and its metamorphosis into a dominant oligopoly, a similar shift also occurred in other parts of the jewellery industry. This shift to product branding was already occurring at the top end of the jewellery industry and was only accelerated by the obligation that De Beers imposed on its sightholders. Without De Beers as a guarantor of price, diamonds could no longer be seen as a store of value as there was no mechanism guaranteeing the annual rate of diamond price increase. As a result of the demise of De Beers and its market position, the response of the jewellery industry as a whole has been generally to increase the level of branding. Indeed, manufacturing and branding of diamonds was required of sightholders in DTC, despite the high failure rate of branding and its absence prior to 2000 (Ever-Zohar, 2007).

Branding should be seen as a mechanism by which the various actors along the value chain attempt to regain market control, but it is most prevalent and generally effective at the top end of the diamond market. De Beers' own rebranding was, in part, from a desire to shift away from the 1990's when it became associated with conflict diamonds (Irwin, 2003). As mentioned above, the shift to branding by sightholders was a direct result of the De Beers strategy, and allocations were provided to those that could increase the demand for diamonds through advertising and marketing (Ever-Zohar, 2007). All major producers i.e., Alrosa, BHP Biliton and Rio Tinto, have imposed similar branding obligations on their customers, following the strategy used by De Beers[47]. It is clearly a policy of attempting to replace the function of the cartel with monopolistic competition in the retail market.

Branding has not only occurred at the level of producers and their clients. There exist numerous forms of branding, including the most well known form, which is branding undertaken by top-end jewellery retail firms such as Cartier, Bvlgari, Tiffani, etc, along with fashion branding, where companies which already have an established fashion brand name have moved into the diamond industry, such as Dior, Gucci and Escada. However, entirely new trends in branding have occurred such as diamond cut brands. These involve particular cutting of diamonds in such a manner that it then becomes subject to patent and trademark rules and therefore the legal system can be used to further enhance the monopoly power along the diamond value chain. Some examples include the 'Leo diamond' or the 'De Vinci Diamond', etc, which are patent and brand protected. The last important novelty in branding is referred to as 'ideas branding', which includes 'the right hand ring' and 'three diamond ring signifying that marriage is about the past, present and future and by extension about buying yet more diamonds[48]. In the final analysis, the intention of branding by De Beers sightholders is to

[47] Ibid.

[48] This particular classification of various forms of diamond marketing was described by Gareth Penny, former MD of De Beers at the Second World Diamond

assure a greater degree of market power and also to remove the generic advertising burden from De Beers. In the process, the branding allows, by extension, the companies, in theory, to assure that the product is not synthetic. If branding is successful and it permits a greater cleavage between the prices of synthetics and natural diamonds, by extension it also creates a greater incentive for forgeries to emerge.

The jewellery industry has also moved to establish its own voluntary code of good practice in 2006, which includes all participants along the pipeline[49]. This code deals with many of the ethical, environmental and health and safety issues confronting the industry including the issue of whether a diamond is synthetic or mined. There is an obligation by jewellers to disclose any synthetic or treated diamond. A system of independent auditing began in 2009 for the 260 members of the organization. None of the mining companies that are members including BHP Billiton, De Beers and Rio Tinto[50] had been audited at the time of writing, and none of the diamond producing companies have been audited for compliance with the standard.

### 4.3 Standards Agencies - Certification and Heightened Standards

It was not until 2007, twenty years after Sumitomo's entry as a synthetic CVD diamond producer, that the Gemological Institute of America (GIA)[51], the most significant of the private lab and standards bodies in the US, started the process of certifying synthetic diamonds[52]. The GIA now laser inscribes "laboratory grown" on diamonds produced in a lab that do not already have an inscription with Federal Trade Commission-approved language, such as "man-made," "lab grown" and branded names such as "Chatham created". The producers of synthetic diamonds have agreed that all their diamonds will be laser inscribed with some type of synthetic nomenclature, but the GIA will ensure that all synthetic diamonds will be laser inscribed with proper disclosure[53]. Similar nomenclature is being developed in the EU. It is important to note that there remains a common interest between the larger synthetic diamond and the mined diamond producers in assuring that the former do not flood the market and undermine profits for all segments of the value chain. It is for this reason that synthetic producers have thus far voluntarily complied with these branding obligations.

Labeling by GIA can, of course, only be undertaken for those diamonds that come before it for a technical assessment and evaluation-it is not legally mandatory in the USA. Moreover, compliance with these standards can only be assured for those firms operating in the US jurisdiction. What remains an important consideration is that, in the event that synthetics become a significant portion of the market and a market price cleavage between mined and synthetics does develop, the possibility of counterfeiting of diamond labels will have to be considered. As yet, no global standards exist; and outside the USA, there can be no assurance that there has not been significant market penetration by synthetics as well as forgeries (Even-Zohar, 2012).

Prior to the entry of synthetics into the mainstream of the jewellery industry in 2007 there was considerable activity in many countries, including Russia and Japan, to produce what were to be synthetic industrial diamonds, but which slipped into the gem quality market. The extent of this slippage over the last 20 years remains unknown, and the industry has not sought to statistically verify the incidence. What is almost impossible to determine is the extent to which these synthetics are already in the jewellery supply chain and in the existing stock simply because the natural and synthetic products are often indistinguishable to the naked eye of specialised diamantaire, and distinguishing many of the melee sized diamonds (<0.2 carat) have never been tested simply because it is not cost effective. Moreover, unlike industrial diamonds, there was no attempt to gather data on the issue. Neither gemologists nor the jewellery industry as a whole are generally willing to discuss the extent to which synthetics have already penetrated the diamond market without any effective product differentiation.

Conference, Antwerp, November 2003, downloaded Feb 2011, http://www.diamondworld.be/diamond-news-archive.php

[49] See http://www.responsiblejewellery.com/downloads/crjp_code_of_practices.pdf downloaded February 2011.

[50] AlRosa, the world's largest diamond producer in 2009, is not a member.

[51] In Europe, the equivalent function to those performed by the GIA is performed by the Hoge Rad Voor Diamant (HRD) or the Belgium High Council, which is involved in grading and certification through RD Antwerp NV.

[52] GIA certification of synthetic diamonds began on January 1st 2007, and, hence can be said to be the date at which the synthetic industry entered the mainstream of the jewellery trade. http://www.gia.edu/lab-reports-services/diamonds/diamond-reports/index.html downloaded March 2011.

[53] GIA Synthetic-Diamond Grading Report Diamonds Update, March 20, 2007, http://diamonds.blogs.com/diamonds_update/diamond_industry_news/page/7/ downloaded March 2011

However, in a recent and very rare study by researchers on yellow melee diamonds in Japan, the researchers found that (Keller, 2008):

> ..... 10% of the loose yellow melee-size diamonds submitted to the lab over a four month period were synthetic. Moreover, approximately half the jewelry items set with yellow melee that the lab received during the same period also contained synthetic diamonds. Although there have been many rumors of synthetic diamond melee in the trade over the last several years, this is one of the first research reports to confirm the potential extent of the problem.

General inference on the penetration by synthetics of the global diamond market is not possible by extrapolating merely from a survey of yellow melee in Japan, as these were the very first synthetic diamond products commercially produced in Japan[54] by Sumitomo when it entered the CVD diamond market in 1986 (Shigley, 1986). The threat that emanates from the substantial penetration of synthetics into the production of melees has resulted in De Beers developing a new machine that can detect synthetic melees. However, the incidence of the nefarious penetration by synthetic diamonds into the jewellery market is becoming more prevalent.

Throughout most of this period, apart from the efforts driven by De Beers[55], there was no attempt by the industry to differentiate mined from natural diamonds, and certainly not to inform jewellery consumers whether the product being purchased may not be a mined diamond. However, this rare data shows the extent to which penetration already exists and what is likely to happen over time in other markets for other gem quality diamond products. There is only anecdotal evidence that penetration of the gem market has already occurred for larger stones with an estimated 400,000 carats of synthetic gem quality CVD and HPHT diamonds being available in the US market alone in 2007 (O' Connel, 2007).

### 4.4 Botswana Synthetics Agreements and Optimal Resource Depletion

Following the announcements by Apollo in 2004 of the development of its gem quality CVD diamonds, the Government of Botswana became keenly aware of the threat posed to its position by the development of synthetics gem quality diamonds. In the renegotiation of the 25 year mining agreement for Jwaneng as well as the marketing arrangement with De Beers, the Government of Botswana had sought assurances that De Beers would not enter the synthetic gem quality market. De Beers did not provide such assurances[56]. There had been widespread speculation that Element 6 will ultimately be faced with no choice but to enter the synthetic gem segment of the diamond market, which it had never done before. In response to this in the suite of agreements signed between Botswana and De Beers, there was an Agreement on Synthetics which provided that in the event that De Beers enters the gem quality synthetic market De Beers will market these gems in a 75-25% joint venture with the Government of Botswana.

While a joint venture with De Beers in the production of synthetic gem quality diamonds may mitigate a part of the losses that Botswana would suffer as a result of the widespread use of synthetics in the jewellery industry, this could not compensate for the losses that would result from the country's loss of economic rents in the mined diamond sector. This is because mining of a rare gem such as diamonds has traditionally brought significant rents whereas an industrial process which is readily replicable will in the longer term derive only normal profits.

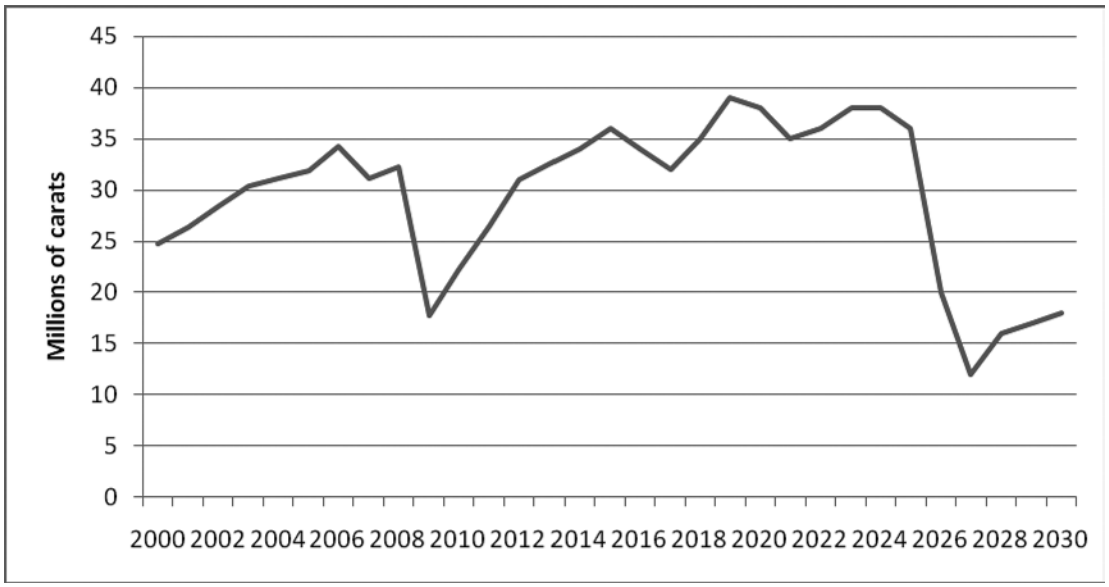
An important secondary effect of the advent of gem quality synthetics is in regards to the policy of an optimal resource depletion of the remaining stock of diamonds in Botswana. By and large, Botswana has been pursuing a passive policy of supplying diamonds in accordance to demand as determined by De Beers.

[54] The original path breaking research was undertaken by Matsumoto S et al (1981).
[55] De Beers is understood to have conducted a similar but private study in the 1990's in Europe and found that more than 30% of the melees were found to be synthetic, source pers. Com. Gemmological Institute of America.
[56] Even–Zohar op cit., page 258.

The advent of market penetration by synthetics decreases the potential for Botswana acting unilaterally or in conjunction with other suppliers to limit production.

The most recent publicly available estimates of total mined diamond production are presented in the figure below. These suggest that if Botswana maintains a policy of supply of diamonds driven by demand i.e. whatever is optimal for De Beers, then production is likely to go into decline at the end of the 2020's. These estimates must be of course taken with some measure of skepticism. The first is that Botswana's diamond production has not in 2013 rebounded to pre-2009 levels of 35 Mc, and has stayed in the mid-20s throughout the crisis from 2009-2012 . Second, these future projections are based on De Beers expectations of demand and the imminent end of the 25 year mining agreement with Botswana around 2030. Third, these projections do not include production from underground mining and in light of the experience of the Botswana 10th Development Plan which predicted a fiscal cliff around 2021, these estimates of resource and revenue depletion are inherently elastic[57]. A more likely and realistic estimate is that diamond production from known reserves will go into significant decline in the 2030's or early 2040's. However, the decline of state revenues which are predicated on the government's 15% share of De Beers and 50% share of Debswana will go into decline long before output begins to decline drastically at the end of mine life. Profitability ultimately depends upon revenue and costs and extraction costs will increase drastically in the 2020's.

**Fig. 9: Actual (pre 2011) and Estimated Diamond (2011-2030) Production in Botswana**




**Source:** De Beers (actual) and 'Botswana Diamonds, 2020 and beyond' Presentation by Dr PHK Kedikilwe Minister of Minerals Energy and water Resources, Amsterdam 2011

The significance of the figure above and the decline in diamond production that it depicts begs the question of whether it is optimal for Botswana to continue its current policy of supplying whatever the market will bear or conducting either unilaterally or in conjunction with the other major supplier such as Alrosa a conscious policy of supply restriction[58]. As has been noted above, diamond discoveries simply have not occurred at a pace to assure supply and it is unclear whether further restrictions on supply will simply accelerate the market penetration of synthetics, and the decline in market price of diamond that must follow. The restriction of mined diamond supply in the gem market may accelerate the demand of lower cost synthetics, and an optimal depletion policy for Botswana may be based on accelerating supply, rather than restricting it, in order not to be left with diamonds of greatly diminished value.

It is unambiguously in the interests of Botswana and all other mined diamond products to maintain the value of diamonds. However, in the absence of mandatory global standards to oblige all suppliers along the value

[57] See Government of Botswana 10th Development Plan, 2009-2013 Volume I , page 55
[58] There is active consideration among the world's two largest platinum suppliers to the establishment of an international cartel arrangement. See' Russia, SA plan an 'Opec' for platinum'05 Apr 2013, *Mail and Guardian* Lynley Donnelly.

chain to document that the diamonds traded are indeed mined diamonds, cannot be assured. The Kimberly process remains the closest international forum that could advocate for such a standard. However, this will not receive international support unless there is first a crisis of confidence in diamond as a store of value, similar to that which occurred during the 'blood diamond' crisis of the 1990's, which in turn resulted in the creation of the Kimberly Process. It is in the long term interest of Botswana and other mined diamond producers to demonstrate to the international community that mandatory international labeling standards are necessary to avoid fraud in international trade. The best way to achieve this is by showing , through the sampling techniques, the extent of penetration that has already occurred. The publication of the results of such a survey will almost certainly undermine short and possibly medium term profitability along the value chain. However, in the long term this is the one piece of evidence that could demonstrate the need for a mandatory global standard and strengthen the viability and profitability of the mined diamond sector and protect it from the threat posed by synthetics.

## 5. Conclusion

The potential for synthetic diamonds to find a significant place in the jewellery end of the market, whether nefariously or legitimately, already exists; and is without doubt accelerating as mined production is unable to keep up with the success of the De Beers marketing in traditional and imerging markets. This appears to have been accepted by the industry[59]. Unlike the 1950's and 1960's when synthetics were first introduced, there is now a highly diffused technology for their production. This technology produces a synthetic product that is both undifferentiable to the naked eye from the mined product, and in many cases superior in quality to the natural product. The cost of brand differentiation is high and, therefore, where there is high transaction costs, there is already evidence from Japan that, when the cost of scientific differentiation is too great, then synthetics will seep into the supply chain as a low cost substitutes to their mined equivalents. The absence of an adequate natural diamond supply, which is projected to increase in the current decade, also suggests that there will be a greater place for synthetics in the mined diamond market. All these add together to create a supply-demand equation which could foreshadow the development of synthetic diamonds in a way that parallels the experience of cultured pearls in the 1930's, where these grew to dominate global pearl production and consumption. This paper has argued that the experience of pearls is particularly relevant to the diamond industry and that cultured pearls played in the destruction of the natural pearl market cannot be overlooked.

Perhaps the single greatest threat comes neither from the two perceived sources-from synthetics directly replacing natural diamond legitimately or otherwise. The widespread use of synthetic annealment and enhancement techniques, as discussed above, which apply synthetic technology to improve the quality and hence the price of mined diamonds, will result in the eventual blurring of the distinction between the two products in the mind of the consumer. This short-term quest for profitability is potentially fatal for the long term vaibility of diamonds as a store of value.

At present, the jewellery industry is engaged in what is called a 4D approach to synthetics-Differentiation, Detection, Disclosure and Documentation. Without detection, disclosure and documentation there can be no product differentiation and the price of gem quality diamond will almost certainly replicate the experience of industrial diamonds. However, a clear distinction between mined and synthetics does not and cannot exist because of the industry practices of enhancement and annealment. The value of diamonds rests ultimately on the perception of their absolute scarcity. The risk that the industry practices create is that, if the public, which is almost completely unaware of such practices, becomes aware of the widespread use of synthetics in jewellery, then the perception of diamonds as an inherently rare and valuable product will vanish and this change in perception could happen very quickly with catastrophic consequences for Botswana. It is because this price decay function is unknowable a priori that we have not attempted to model the effects of synthetics on prices and hence Botswana government revenues.

[59] Even –Zohar, C. *Diamond Intelligence Brief*, No 763, 13 June 2013 'Let's Stop Kidding Ourselves: Synthetic Diamonds Have Invisibly Integrated Into Our Polished Supplies; Are We Heading For Industry Suicide? Man-Made Mining-Output Growth Outpaces Natural Mine Expansion; Entry Barriers into Synthetics Have Gone Down'

The response of the industry to the threat of synthetics has been through branding, certification and documentation of the mined and synthetic diamonds. While these are important steps, the industry in the main markets of the US and EU has not taken the obvious step of informing the public of the extent of synthetics in the products that are purchased.

The testing agencies, such as the GIA and their European counterparts, have either not undertaken or not divulged the extent of synthetic penetration, whether nefarious or otherwise, of the mined diamond market. It is incumbent upon the industry standard setting bodies to inform the public through a thorough testing of existing jewellery on a scientific basis to determine the extent of the practices, as was the case in Japan. Voluntary codes that attempt to guarantee that what the consumer is purchasing is, indeed, a completely natural product do exist, but these are not obligatory and consumers are frequently not sufficiently well informed of the relevant issues to even ask at point of purchase. While the results of such a random sampling may have adverse effects temporarily, they would almost certainly result in more robust global standards being developed, which would be in the long term interests of both the industry and the consumer.

For Botswana, which has sufficient deposits of diamonds to remain an important supplier on the world market for at least the next two decades, the stakes could not be greater. Botswana is also the world's most diamond dependent economy and a catastrophic decline in price and profitability of the sector as a result of a loss of consumer confidence in the long term value of diamond as a store of value is a definite but unquantifiable risk. That risk is being increased by the industry through its use of synthetic annealment and enhancement techniques to increase the value of mined diamonds. The rapid penetration of synthetics into the gem quality market remains a possibility throughout the present decade and there is increasing and recent evidence that this is already occurring and is likely to accelerate given the global supply of mined diamonds expected post-2017. There is already mounting scientific evidence of penetration of synthetics into the bottom end of the jewellery market where the transaction cost of product differentiation is too high, given the value of the diamond. What remains certain is that the penetration of synthetic gem quality diamonds, in a way and at a pace that resembles the experience of industrial diamonds, where prices declined over a 30-50 year period is highly improbable. The pace and extent of diffusion of technology, the number of countries and firms with access and interest in expanding production means that a policy in Botswana of decreasing the pace of depletion of the existing stock of mined diamonds may prove counterproductive, and the optimum policy may prove to be the opposite i.e. the rapid depletion of existing stocks.

Ironically, the origins of the problem of synthetics stem in no small measure from the very success of De Beers marketing campaigns in Asia, which is increasing demand in non-traditional markets such as Inida and China. This is occurring just at a time when the mined diamond industry appears unable to discover new significant deposits. But along with the growing excess demand for mined diamonds and the nefarious penetration of the market by synthetics, it is the short term profit maximizing practices of enhancement and annealment of mined diamonds using synthetic techniques by the jewellery industry that most undermines the most basic of the 4D's i.e. differentiation, by blurring the distinction between mined and synthetic products.

It has been argued that it is in the interest of Botswana to move to mandatory global standards along the diamond value chain, which differentiate mined from synthetic diamonds. However, the international community is unlikely to support such a standard unless it can be demonstrated that fraud is occurring. This can be achieved by replicating, on an global scale, the Japanese research undertaken on the matter. However, given the likely results this could cause a short to medium term crisis in the market and undermine the profitability of the producers, including De Beers. In the longer term however only a mandatory global standard that clearly differentiates mined from synthetic and enhanced or annealed diamonds can protect the commercial value of Botswana's assets.

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