PLATINUM ESSENTIALS

Platinum 101 – An introduction for investors

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June 2020

Platinum is a commodity with unique characteristics and drivers

Platinum benefits from being both an industrial and precious metal, 30 times rarer than gold, and an effective portfolio diversifier. Many of platinum's varied applications provide solutions highly relevant to global challenges, now and into the future. This dynamic forms the basis of an investment case that is compelling yet often misunderstood.

Platinum mine supply is unusually highly concentrated, with over 70% of global mine supply coming from a relatively small geographic region in South Africa. Here supply has declined from a peak of 5.3 moz in 2006 to 4.4 moz in 2019 due largely to declining margins and limited capital investment. Platinum supply from recycling increased from 1.4 moz to 2.2 moz over the same period leaving total supply in 2019 0.6% below that in 2006.

Platinum demand is diverse across four main segments: automotive, industrial, jewellery and investment averaging over the past 5 years: 40%, 24%, 30% and 6% respectively.

Platinum is currently characterised by constrained supply and flat demand but with material demand growth potential and with platinum at historic discounts to itself, to gold and to palladium.

The palladium and platinum markets are interlinked with regard to supply as well as demand. They are co-products or by-products in the majority of their mining locations, and they are substitutes for each other in several industrial applications, most importantly in the most dominant use of palladium; in automotive catalysts.

The current sharply contrasting prices and market balances between the palladium and platinum markets suggests material demand rebalancing is inevitable, with substitution already underway.

In this edition of ***Platinum Essentials***, we present a detailed analysis of the platinum market to provide a framework for platinum investors or investors considering platinum as an investment asset; and market participants who may be new to platinum or want a refresher on its fundamentals.

The impacts of the COVID-19 pandemic on global economies and markets continue to unfold. These impacts on the platinum market in 2020 are expected to reduce both demand and supply. Dynamics peculiar to platinum and unrelated to the pandemic have reduced supply further and demand growth potential remains strong. However, forecasts of platinum supply and demand are likely to remain volatile for several months, particularly until Europe, North America and South Africa contain the spread of COVID-19 and the impact of the wide range of economic effects of the pandemic on platinum can be evaluated more accurately.

WPIC's ***Platinum Essentials*** publication explores topics affecting platinum as an asset class. This is different to ***Platinum Perspectives***, which provides the WPIC view on a specific topic affecting platinum's supply, demand or value dynamics. *Note: Platinum 101 first published in Oct'17.*

Contents

What is platinum?

Platinum is a hard, silvery metal, that is a precious metal and an industrial metal. Platinum was discovered in 1735, thousands of years after gold due to its higher melting point (1,768°C, vs gold at 1,064°C), and the fact that platinum is very rarely found in its pure form in nature. Platinum is heavier or denser than gold (21.5 g/cm3 vs. 19.3 g/cm3) and more noble (less reactive) but in refined metal terms platinum is thirty times rarer than gold.

Platinum metal can be produced used and stored in the forms below; with different forms of pure metal useful for different types of applications.

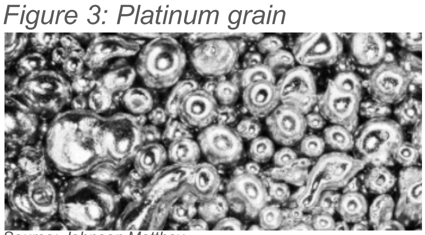
Figure 1: Platinum ingot

Source: Valcambi
Uses: storage and investment

Figure 2: Platinum sponge

Source: Heraeus
Uses: industrial including autocatalyst

Figure 3: Platinum grain



Source: Johnson Matthey
Uses: jewellery fabrication

Platinum occurs at very low concentrations in the Earth's crust (only the 72nd most common, out of 92 natural elements) and is the most important of the six Platinum Group Metals (PGMs). Platinum's importance as an industrial metal is mainly due to its catalytic properties, i.e. its ability to speed up a chemical reaction without itself being changed in the process. In manufacturing and industry, platinum's unique properties – catalytic effect, high melting point, malleability, and resistance to corrosion – have led to a wide and sometimes unexpected range of applications.

Platinum is the 78th element of the periodic table and is the third most dense of the six PGMs, at 21.5 g/cm^3, compared to 12 g/cm3 for palladium, 12.1 g/cm^3 for ruthenium, 12.4 g/cm^3 for rhodium, 22.6 g/cm^3 for osmium, and 22.7 g/cm^3 for iridium. Platinum's melting point is 1,768 ºC compared to 1,555 ºC for palladium, 1,964 ºC for rhodium, 2,334 ºC for ruthenium, 2,443 ºC for Iridium and 3,033 ºC for osmium.

Where and how is platinum 'made'?

Where is platinum found?

Thirty times rarer than gold, platinum occurs at very low concentrations in the Earth's crust. When compared to gold and silver mine production the rarity of platinum is highlighted further. In 2019, the mined production of silver, gold and platinum was 836 moz, 111 moz and 6 moz, respectively.

At the end of 2018, known global platinum reserves totalled around 248 moz (c.7,720 tonnes) according to data compiled from company reports, reserve and resource statements, NI 43-101 technical reports and feasibility studies.

There are only four countries in the world that have platinum mining operations of any significance and of these South Africa has the largest platinum resources by far.

Over 80% of the world's economically viable platinum-bearing deposits (reserves) are located in the Bushveld Igneous Complex (Bushveld) which is in the northern part of South Africa. The balance is largely in Zimbabwe (the Great Dyke deposit), Russia, and North America. Southern Africa is the only primary source of platinum, with platinum in Russia and North America mined as a by-product of other metals (mainly nickel and palladium, respectively).

Platinum is very rarely found in isolation, it is more commonly found alongside other metals; primarily palladium and the other PGMs; and base metals such as nickel, copper and chrome. Platinum is extracted, processed and purified through a complex series of physical and chemical processes, namely mining, concentrating, smelting and refining.

South Africa's Bushveld Igneous Complex (Bushveld)

The two types of Bushveld PGM ore bodies, in the western and eastern parts ("limbs") of the Bushveld, are the Merensky and Upper Group2 (UG2) ore bodies. Merensky, which historically provided the majority of PGMs, was shallower, higher grade, and higher revenue compared to UG2 ore. However, with increasing depletion of Merensky ore, more UG2 ore was mined. Platreef ore is found in the northern limb of the Bushveld. It is much shallower than Merensky and UG2 and is mined from several open pit operations. It has a higher palladium and base metal content with different mine economics.

Figure 4: PGM ore types in the Bushveld and characteristics

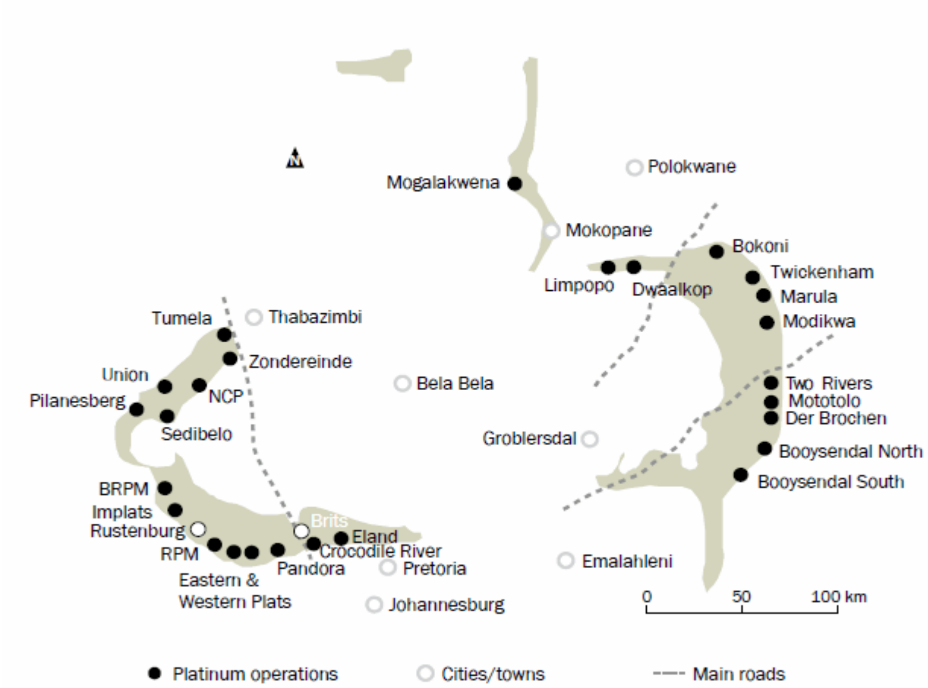
Ore type	Merensky	UG2	Platreef
Location in the Bushveld	Western limb and Eastern limb	Western limb and Eastern limb	Northern limb
Depth (m)	Up to 1.5km deep	Up to 1.7km deep	Currently mined upto 250m deep
PGM - 4E	Platinum (62%), Palladium (29%), Rhodium (4%), Gold (5%)	Platinum (53%), Palladium (36%), Rhodium (10%), Gold (1%)	Platinum (43%), Palladium (36%), Rhodium (10%), Gold (1%)
Grades (grams 4E PGMs / tonne)	c.4-6	c.3-5	c.2-5
Base metal contribution	high (0.2% nickel, 0.1% copper	low (0.1% nickel, 0.01% copper)	higher (0.25% nickel, 0.15% copper)
Processing temperature	high	very high (due to high chrome content)	high

Source: Company Reports, WPIC Research

The different ore types in the Bushveld have different geological characteristics (i.e. depth of deposit, concentration of PGMs) and different ratios of metals (i.e. ratio of platinum to palladium, rhodium, and gold; and concentration of base metals such as chrome, nickel and copper).

In the western and eastern parts of the Bushveld, PGM ore is traditionally extracted from underground mines (usually between 700 metres and 1,700 metres deep).In the northern part of the Bushveld, the PGM ore (Platreef) is close enough to the surface for some mining to be open pit.

Figure 5: Bushveld PGM operations

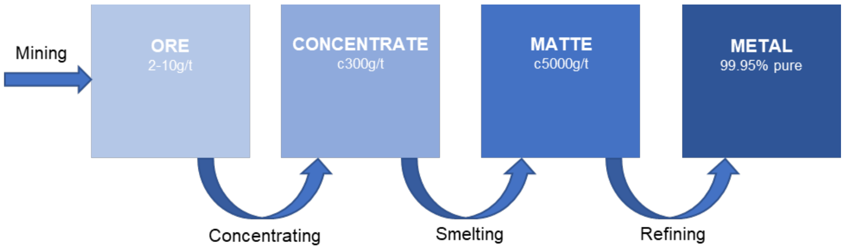


Source: Minerals Council South Africa

How is platinum mined and refined?

Platinum is extracted, processed and purified through a complex series of physical and chemical processes, namely mining, concentrating, smelting and refining. For PGM orebodies the production process requires the extraction of several metals including platinum as shown and described below.

Figure 6: Overview of PGM production



Source: WPIC Research, concentrations shown are typical for Southern African production

Mining

Mining of PGM ores is mostly conducted via underground mines with less than 20% from open pit mines. In South Africa, the depth of the underground mines typically ranges between 700 metres and 1,700 metres, while in Russia the range is between 400 metres and 2,000 metres. The underground mining method entails vertical or inclined shafts being drilled into or adjacent to the ore body (a process that, for vertical shafts, can take up to ten years), from which horizontal and / or diagonal paths are drilled to gain access to the ore body. At the ore face, horizontal channels are drilled, explosives are placed into the holes and blasted to liberate the ore. The ore is transported to the surface through a network of underground ore handling machinery.

In open pit mines, the ore is accessed directly from the surface rather than through a shaft. Unlike underground mining, drilling and blasting in an open pit mine is mechanised. Trucks and shovels can be used to move large volumes of ore; which can make open pit mining quicker, cheaper and safer than underground mining.

Concentrating

The mined ore is crushed and milled to liberate the minerals which contain PGMs. Thereafter, the material undergoes a chemical process known as froth flotation. This uses a combination of reagents and the addition of air to create bubbles to which the PGM-containing particles attach. This is done to ensure that the optimal grade and recovery is achieved. In this process, the concentration is increased from 2-6g of 4E (platinum, palladium, rhodium and gold) per tonne of ore, to around 300g of 4E per tonne in concentrate.

Smelting

The concentrate is then dried and processed through a smelter. The concentrate is heated in a furnace to temperatures which can exceed 1,500°C. PGM smelting temperatures are high due to the presence of chrome in the ore. Within the furnace, the matte rises to the surface and the waste product discarded. After smelting the matte is treated in a converter to remove sulphur. During the smelting and converting process, the concentration is increased from 300g 4E per tonne to 5,000g 4E per tonne.

Refining

The matte is processed through a base metals refinery to extract copper, nickel and other base metals. It is then routed to a precious metals' refinery for extraction and purification of the PGMs. Gold, palladium and platinum are generally the first to be extracted, followed by iridium and rhodium. Precipitation, solvent extraction and ion-exchange technologies are used across producers in the refining process. Refined metals have a purity of over 99.95% and are usually in the form of sponge (pure metal powder) or granules (for industrial applications) or ingot (for storage / investment).

Platinum supply trends

Platinum mine supply is unusually highly concentrated, with over 70% of global mine supply coming from a relatively small geographic region in South Africa. Here supply has declined from a peak of 5.3 moz in 2006 to 4.4 moz in 2019 due largely to declining margins and limited capital investment. Over 80% of this supply is from underground hard-rock narrow-seam mining with high fixed costs, high labour costs and production levels that take significant cost and time to increase or decrease.

Platinum mine supply from non-Southern African mines (South Africa and Zimbabwe) is mostly produced as a by-product, to Nickel in Russia and Palladium in North America, and has fallen from 1.4 moz in 2006 to 0.9 moz in 2019. Supply from Zimbabwe increased over the same period from 165 koz to 721 koz but has averaged 700 koz over the past 5 years.

Platinum supply from recycling increased from 1.4 moz in 2006 to 2.2 moz in 2019 leaving total platinum supply 0.6% below that in 2006.

Platinum mine supply trends

Mining activity requires significant initial investment to discover and evaluate a deposit, develop the mine and produce refined metal. To make this an economically sensible decision, the revenue from the future sale of the metal minus the associated costs of running the mine (operating costs, capital expenditure, taxes, financing costs etc) should lead to a good return on the initial investment (many mining companies use a 15% Internal Rate of Return or IRR as a benchmark). Often, the time from discovery of PGMs in the ground to mine development and eventual production can take over a decade. We outline some of the factors that should impact primary platinum supply (i.e. as conducted by PGM miners) below.

1. **Available reserves / resources** – Platinum is a finite material, and the total amount that can be produced is limited by the amount that is in the ground.
2. **Platinum price** – historically PGM miners typically generated c60% of revenues from platinum with the balance from by-products. Given the cost base is largely fixed, the operational leverage to platinum prices is very high, with fluctuations in prices broadly flowing directly to earnings and cash flow. This is especially pertinent in a low margin environment, where e.g. a 10% swing in platinum prices could turn many PGM miners from cash and earnings negative to cash and earnings positive.
3. **Palladium and other PGM prices** – historically PGM miners typically generated 20-30% of revenues from palladium, and the 10%-20% balance (excluding platinum) from rhodium, gold, nickel, copper, chrome and other (minor) PGMs. Fluctuations in these commodity prices are also a significant source of operational leverage.
4. **Exchange rates (principally the ZAR vs US$)** – In PGM mining, 80-90% of operating costs are in the local currency. Labour (c60% of operating costs); and electricity (c15% of operating costs) are inextricably linked to the local economy. Metal sales are in US$ as PGMs trade on global markets almost entirely priced in US$. As over 70% of primary platinum supply is from South Africa, the focus is on the ZAR vs the US$.

There is a perception that the ZAR should have a strong effect on the platinum price (i.e. a weakening ZAR should lead to a falling US$ platinum price). This is expected because i.e. if the ZAR weakens, the PGM miners' costs decrease (in USD terms) and the increased ZAR margin should incentivise these miners to produce more platinum, weakening the supply demand balance, and therefore the platinum price (in USD) should decrease. This correlation between the dominant producer currency and the commodity price works as a natural hedge in many other commodities; e.g. the Chilean peso and the copper price (given Chile produces c30% of global mined copper) and the Australian dollar and the iron ore price (given Australia produces c50% of the global seaborne iron ore).

The platinum price has indeed shown some sensitivity to the ZAR in the past (although notably less sensitivity to the ZAR's strength than its weakness). However, in recent past, periods of ZAR weakness have not led to increases in platinum production. This is due to:

- **Operational constraints** – there are capacity constraints on the amount of ore that can be physically brought out of the ground at any time;
- **Geological constraints** – the concentration of PGMs in a single mine is relatively uniform. Therefore, PGM miners cannot generally reformulate the mine plan to focus on areas of higher metal concentration. This could improve the mine economics by getting more metal from the same volume of ore (and therefore a similar operating cost). This is possible in other metals (e.g. gold high-grading); and is a common approach to material downturn in prices, but difficult for PGM miners.

It could be argued that if movements in the ZAR are sustained, e.g. over a period of several years, this could potentially have an impact on longer term mine production options. However, the physical supply of platinum is much less reactive to the ZAR than platinum US$ price movements would suggest.

PGM ZAR basket price – The real driver of mine economics

Bringing (almost all) the above drivers into a single measure, we show below the "collective" price of the basket of PGMs in ZAR terms. The charts below highlight the material difference between the movements in the PGM ZAR basket price and the platinum USD price, especially over the past five years.

Figure 7: Platinum price (USD / troy ounce)

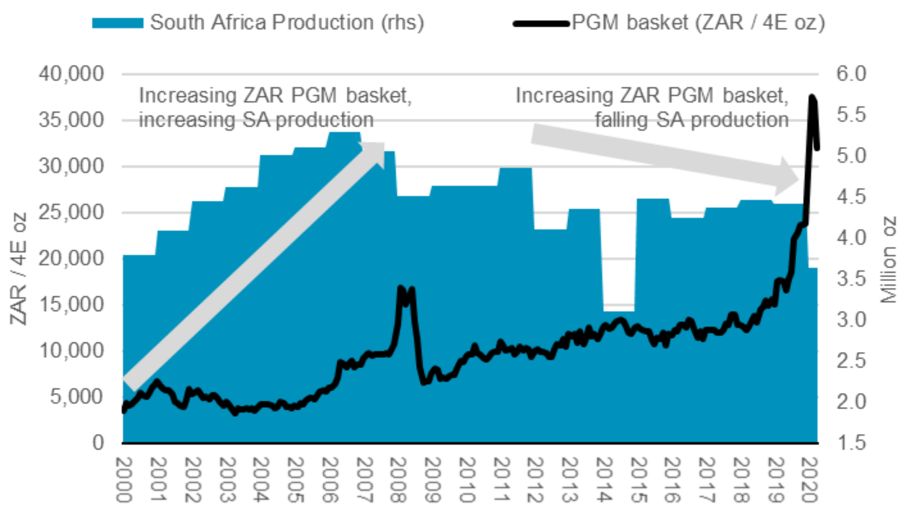
Source: Bloomberg

Figure 8: PGM ZAR basket price (ZAR / 4E troy ounce)

*Source: Bloomberg, WPIC Research. Assumes PGM 4E production volume is 58% platinum, 32% palladium, 8% rhodium and 2% gold, and calculated as 58%*platinum price + 32%*palladium price + 8%*rhodium price + 2%*gold price. Denominator is volume of platinum + palladium + rhodium + gold produced (4E troy ounces). Ignores minor metal contribution.*

We show below that in recent years, despite the increase in the ZAR PGM basket price, South Africa's production has fallen. Therefore, although a higher ZAR PGM basket price should have incentivised SA PGM miners to increase production, that has not materialised.

Figure 9: Platinum price (USD / troy ounce)



*Source: Bloomberg, WPIC Research. Assumes PGM 4E production volume is 58% platinum, 32% palladium, 8% rhodium and 2% gold, and calculated as 58%*platinum price + 32%*palladium price + 8%*rhodium price + 2%*gold price. Denominator is volume of platinum + palladium + rhodium + gold produced (4E troy ounces). Ignores minor metal contribution.*

The PGM ZAR basket price we present above is a simplification of the impact on mine economics as:

- it excludes base metal revenue contributions (which are often deducted from the mine unit cost, in order to make the PGM basket price comparable with the actual unit cost);
- it excludes revenue contributions of minor PGMs (sometimes also deducted from unit costs, as per the above);
- it ignores the fact that each mine's relative metal volume contribution (i.e. prill split) is slightly different, and could vary over time; e.g. if the ratio of UG2 to Merensky ore changes, and;
- it ignores the fact that many mines sell concentrate (to be processed by a third party) rather than finished metal; and as such only receive c85-90% the basket price. This affects up to a third of South Africa's platinum production, varying over time with the change in ownership of mines, mineral rights and processing facilities.

Despite these simplifications, the PGM ZAR basket price provides a better barometer of mine economics than the platinum USD price, especially post 2011; where the two measures have gone in very different directions.

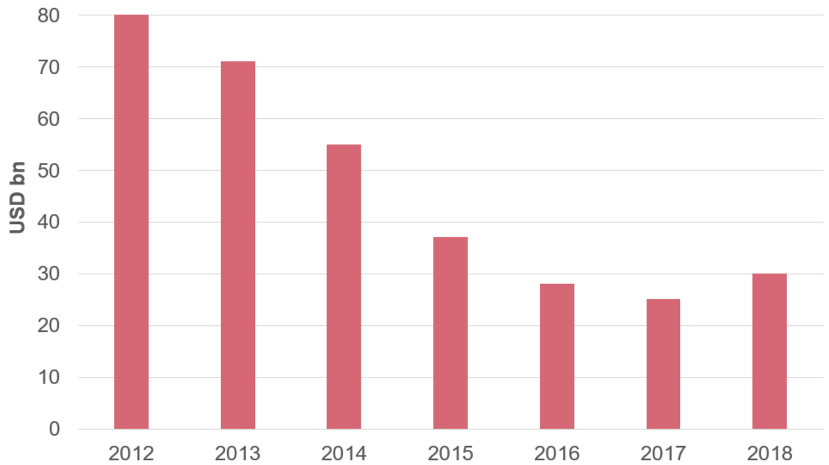
Other factors influencing platinum mine supply

- **Regulatory / legal environment** – Each country has its own set of complex regulations and policies regarding mining. A mine investment is usually a multi-decade undertaking. In South Africa, mineral resources are owned by the government, but companies have mining rights (effectively licences), obtained from the government which allow them to operate mines. This comes with responsibilities including those regarding safety, environment, labour, procurement, interaction with local communities and equity ownership. The applicable law is the Mineral and Petroleum Resources Development Act, 2002 (MPRDA), and the Mining Charter is an agreement between the government and the companies on how to implement that law.

  The Mining Charter was originally agreed in 2004 and included several key aims to address the complex socioeconomic and political past in South Africa. This included a 26% ownership by historically disadvantaged citizens. PGM mining companies have close working relationships with the state regarding mining policy and its implementation and this is aided by the Minerals Council South Africa. Achievements against the mining act and charter were reviewed in 2014 and amendments to these continue.

- **Global Mining trends** – Total annual global mining capital investment last peaked in 2012, at close to $80 bn at the same time as peak prices of industrial metals. Annual capital investment fell to $25 bn by 2017, with a modest year-on-year recovery in 2018. Research by PwC, shows that PGM mining capital investment peaked in 2008, also the year in which platinum peaked at $2,250/oz. The PGM mining sector has had a longer period of declining capital investment than the global mining sector. Sustained high PGM US$ prices will typically be required to reverse this trend.

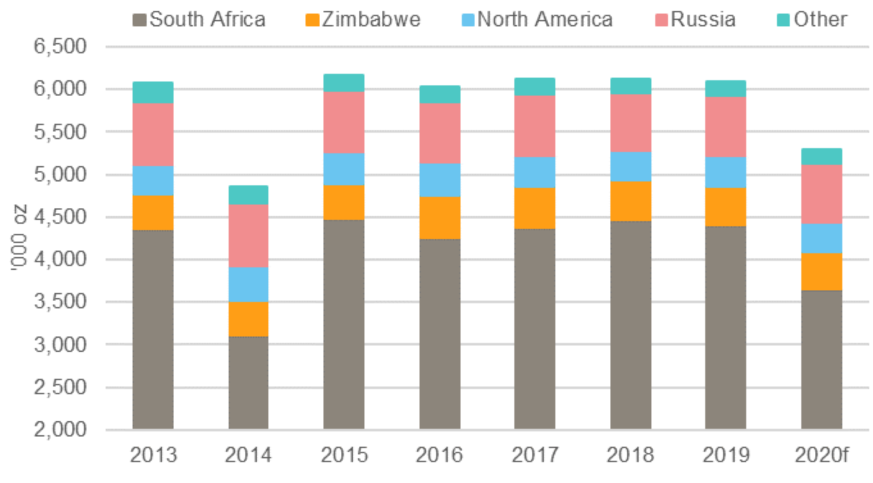
Figure 10: Global mine capital expenditure (US$ bn)



Source: PwC

- **Commodity and metal prices** – The relative portion of revenue per metal has also changed for South African PGM mining companies. In 2010, PGM miners earned c.60% of revenue from platinum sales, and c.10% from palladium. By 2019, this revenue split had shifted to c.30% for platinum and c.40% for palladium. South African mine supply of platinum reduced from 4.64 moz in 2010 to 4.4 moz in 2019. This decrease was mainly due to uneconomic production being stopped, with the closure of several mine shafts.

Figure 11: Total platinum production (000's troy ounces)

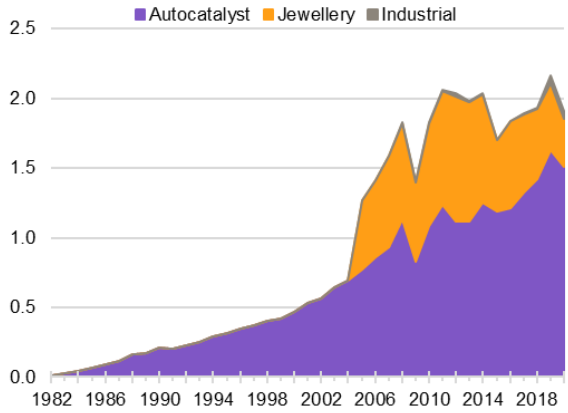


Source: WPIC Platinum Quarterly, PQ Q1 2020

Platinum recycling supply trends

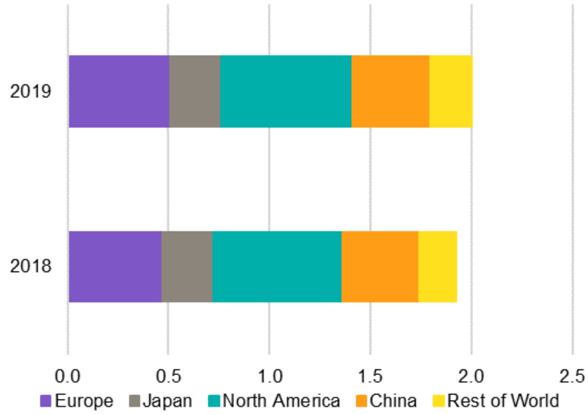
Platinum is highly recyclable; and as the number of applications for platinum grow over time; products which contain platinum get to their end of life; and the valuable platinum metal is recycled. This source of supply has become more meaningful post 2000. Ultimately the stream of secondary supply is a function of historical platinum consumption, so it is unlikely that these go in opposite directions for a sustained time.

Figure 12: Platinum recycling supply by source (million troy ounces)



Source: Source: Johnson Matthey (to 2012) SFA (2013-2018), Metals Focus (from 2019), WPIC Research

Figure 13: Secondary platinum supply by region (million troy ounces)



Source: WPIC Research, SFA (Oxford)

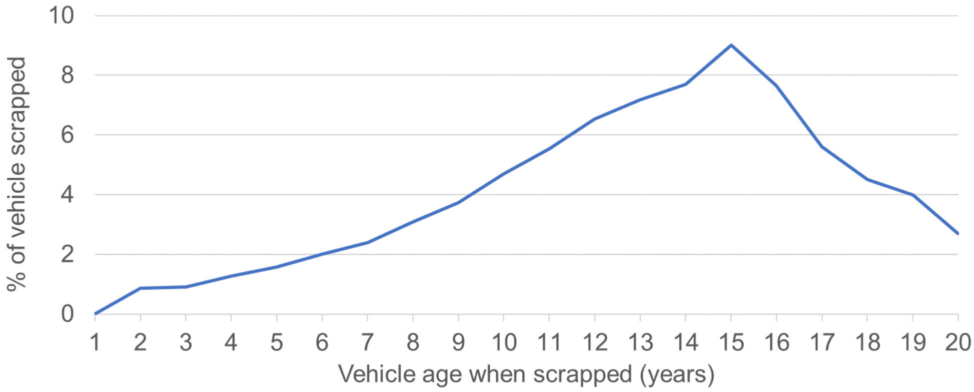
The primary source of recycled platinum arises from recycled automotive emissions control catalysts when vehicles reach the end of their lives. Most platinum is used in diesel cars and trucks and in 2019 almost 2.9 moz of platinum was used in the manufacture of vehicles. Recycled platinum from jewellery in 2019 was 477 koz but has averaged 700 koz annually since 2006.

Autocatalyst recycling follows the end-of-life vehicle scrappage profiles in various regions and platinum supply from this source reflects the loadings per used catalyst. This loading reflects the amount of metal necessary, at the time the vehicle was produced, to achieve the emissions level per region over time. It is this loading that governs secondary platinum volumes and consequently the supply is relatively price inelastic. As the catalyst recycle business grew following the introduction of catalysts in the 1970's, recycling became a mature business with largely fixed, yet low, margins. This is because the price paid for scrap catalysts is based on the metal content at market prices.

This also means that even at very low PGM prices these end-of-life catalysts will always be processed and explains further the inelastic nature of this supply. Consequently, almost all catalysts are removed and recycled. In 2019, recycled material from autocatalysis, jewellery and electronic sectors accounted for 26% (2.2 moz) of total platinum supply. This rose from 1.4 moz (18% of supply) in 2006 as catalyst recycling matured and the jewellery industry was in a strong growth phase.

Meeting tighter emissions limits was the dominant reason for increased PGM usage rather than the number of cars produced (see Figure 19 on page 14). The supply from recycling reflects this increase in loading but the rate of growth is diluted by the very flat scrappage profile. This explains why recycled auto catalyst platinum supply has followed a relatively smooth growth path since the mid-2000s.

Figure 14: Annual US auto scrappage rates

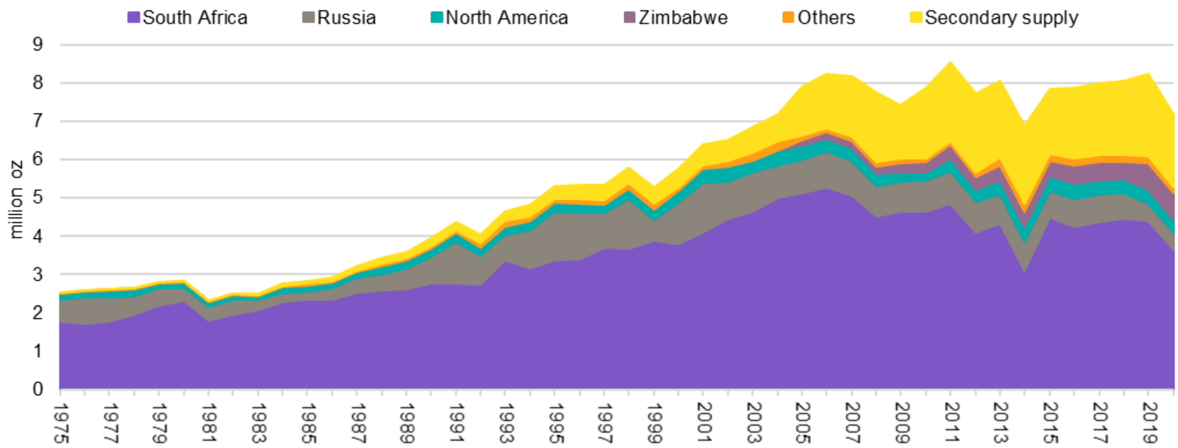


Source: US Department of Transport

Recycled supply from other end-use sectors, such as jewellery and electronics, represent a smaller proportion of overall recycled supply. Jewellery recycling tends to follow sales volumes in China while electronic scrap is much smaller and more stable.

Total Platinum supply

Figure 15: Total platinum supply (Platinum mine and recycled supply)



Source: Johnson Matthey (to 2012) SFA (2013-2018), Metals Focus (2019 and 2020f), WPIC Research

What is platinum used for?

Platinum's physical and catalytic properties mean it has a wide range of uses. Currently, automotive represents the highest end use for platinum (36-43%); followed by jewellery (26-35%), industrial applications (21-26%) and physical and physically backed investments (0-15%).

The 5-year ranges (2015 to 2019) for the four main demand segments of platinum are shown below.

Figure 16: Platinum end-uses

Main markets; Europe, Japan Platinum is used in catalysts to reduce harmful emissions Fuel cell vehicles, a type of electric car, also use platinum	Main markets; North America, China Platinum is seen as superior to gold (and priced accordingly) – so jewellers make a higher margin Platinum seen as metal of love	Main markets; China, North America Platinum is used in applications such as fertiliser manufacture, hard disks and pacemakers	Investors can buy Exchange Traded Funds (ETFs), bars, coins, etc Investors can also can exposure through platinum futures equities etc

Source: WPIC Research

Automotive demand

The largest use of platinum is in automotive applications, specifically catalytic converters. Platinum is an excellent catalyst and is instrumental in reducing the emissions of the three main emissions from internal combustion engines: unburned hydrocarbons (HC); carbon monoxide (CO) and oxides of nitrogen. Emissions continue to be subject to increasingly strict regulations in most countries around the World.

Platinum automotive demand is determined by the four main drivers detailed below. The same factors drive automotive demand for palladium and rhodium; and these trends are examined below. Because automotive is the largest source of platinum demand, perceptions of automotive trends have a disproportionate effect on the perception of platinum's fundamentals.

1) **Vehicle numbers** – The more vehicles on the road, the more autocatalysts are needed which increases the total PGMs required or demand. Vehicle production and sales are driven by economic growth, and consumer trends. Shared vehicle use for example (Uber, Lyft) could reduce vehicle ownership in developed markets. The opposite is true in growing markets as vehicle ownership per capita grows. The negative impact of the COVID-19 pandemic will be material on vehicle sales although the exact impact is still being evaluated.

2) **Vehicle sizes** - Large vehicles typically have large or more powerful combustion engines and require higher amounts of PGMs per vehicle to achieve the regulated emissions levels. Historically, this relationship was broadly linear; i.e. a 1.5 litre vehicle needed about half as much PGM content as a 3 litre one did. So, a consumer trend for larger vehicles had a positive impact on PGM demand (and vice versa). This remains largely true although higher performance vehicles of similar engine size can have far higher loadings and fear of missing regulatory compliance has resulted in over engineering. This is where more metal is used to ensure emissions regulation compliance under all conditions and mainly due to fears after the Dieselgate scandal in 2015 (cheating in the US) and introduction of more stringent on-road tests that replaced in-laboratory ones.

3) **Powertrain trends** - Different powertrains (e.g. diesel, gasoline hybrid, battery electric and fuel cell electric) have significantly different loadings of platinum, palladium and rhodium. Only Battery Electric Vehicles do not contain any PGMs. Historically, diesel vehicles have the highest platinum loadings of internal combustion engine vehicles. A higher share of diesel vehicles on the road would increase platinum demand (and vice versa).

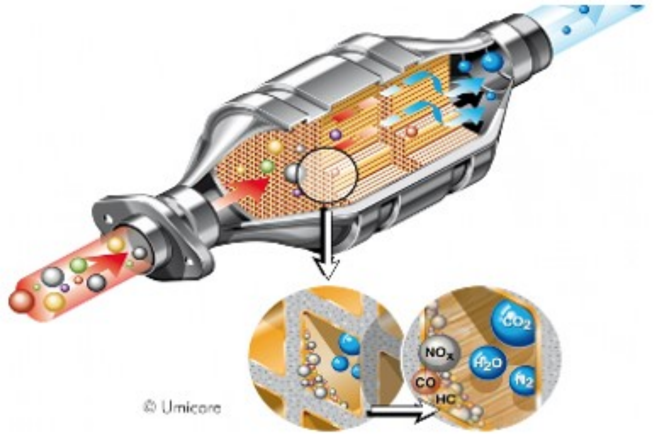
Figure 17: Vehicle powertrain breakdown

Powertrain	Acronym	Description	PGM content
Diesel conventional	d	Conventional vehicle with a diesel engine	5 - 10g of total PGM content; high platinum, low palladium, past LNT some rhodium, SCR no rhodium
Gasoline conventional		Conventional vehicle with a gasoline engine	2 - 7g of total PGM content; high palladium, low to no platinum and low rhodium. (some rhodium essential)
Diesel mild hybrid	mHEV, 48V	Conventional diesel car with a small 48 volt battery and electric motor to help with performance and fuel efficiency. Cannot run on battery power alone	Likely to contain similar PGM loadings to a conventional diesel vehicle - similar combustion engine size
Gasoline mild hybrid	mHEV, 48V	Conventional gasoline car with a small 48 volt battery and electric motor to help with performance and fuel efficiency. Cannot run on battery power alone	Likely to contain similar PGM loadings to a conventional gasoline vehicle - similar combustion engine size
Diesel hybrid	d, HEV	Contains both a diesel combustion engine and a large battery, can run on either battery or combustion engine alone or both in parallel. Historically very few such models on offer	Likely contains similar PGM loadings to a conventional diesel vehicle. Smaller combustion engine, variable technology
Gasoline hybrid	HEV	Contains both a diesel combustion engine and a large battery, can run on either battery or combustion engine alone or both in parallel. Historically dominant hybrid as many small gasoline engines when designed.	Likely contains similar PGM loadings to a conventional gasoline vehicle. Smaller combustion engine but runs intermittently (at lower average temperature, so higher PGMs relative to combustion engine size)
Diesel plug-in hybrid	d, PHEV dPHEV	Like a HEV (can run on battery, diesel combustion engine or both), can run solely on battery power for at least 10 miles, battery can be plugged in to be recharged	Likely contains similar PGM loadings to a conventional diesel vehicle. Similar or smaller combustion engine, variable technology
Gasoline plug-in hybrid	PHEV	Like a HEV (can run on battery, gasoline combustion engine or both), can run solely on battery power for at least 10 miles, battery can be plugged in to be recharged	Likely contains similar PGM loadings to a conventional gasoline vehicle. Similar or smaller combustion engine but runs intermittently (at lower average temperature, so higher PGMs relative to combustion engine size)
Battery Electric Vehicle	BEV	Large battery stores electricity. Only runs on battery power. Normal charge (10 h), quick charge (30 min) high power and reduces battery life	Contains no PGMs
Fuel Cell Electric Vehicle	FCEV	Contains a fuel cell which uses hydrogen to generate electricity used to charge a small battery and/or drive electric motor directly (5 mins to refuel H_2, good range)	Currently contain 30-60g of platinum per vehicle; long-term target of 10 - 15g of platinum

Source: WPIC Research

4) **Technology changes (including substitution)** – The dominant driver of increased platinum automotive use has been to meet tightening emissions legislation. Countries and regions have applied progressively more stringent emission limits on HC, CO, CO_2, NOx, NH_3 and particulates emitted from vehicles. Regulation is typically most stringent in developed countries with developing countries following a similar trend. However, the China 6 and China VI emissions being implemented for cars and tricks respectively are more stringent that the EU and US regulations. This reverses historic developments where China lagged the west. All else being equal, to achieve lower emissions from a (non-battery) vehicle a higher volume of PGM content is needed. Technological improvements can go some way to offset this; autocatalyst manufacturers have significantly improved the efficiency of catalysts in meeting emissions regulations and this has allowed them to ‘thrift’ PGM usage per catalyst. This has been achieved by, for example, advances in wash-coat formulations (the layer on the autocatalyst surface that holds PGM molecules in place), and the tailoring of catalysts to individual vehicle models, as well as the impact of reduced sulphur content in fuels. Patterns of use between platinum, palladium and rhodium in autocatalysts have varied over time, while emissions standards have grown ever more stringent. Usage is determined by multiple factors including the effectiveness, availability and price of each metal. The catalytic efficiency of each metal is influenced by engine temperature, fuel type, fuel quality and durability of the autocatalyst’s washcoat. Today, platinum is predominantly used in autocatalysts in diesel vehicles, with palladium principally in those in gasoline vehicles. However, this usage is shifting, with substitution of platinum for palladium occurring due to sustained palladium deficits and the high price of palladium, now still over US$1,000/oz higher than platinum.

Figure 18: A typical autocatalyst

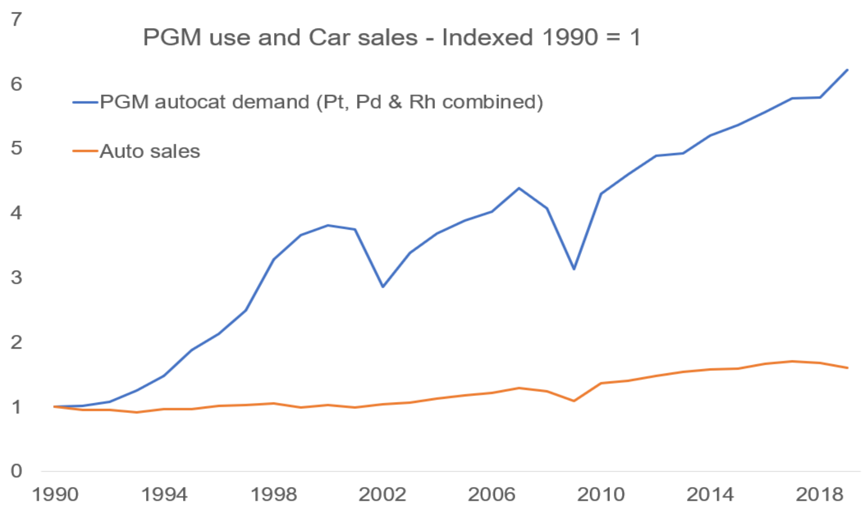


Source: Umicore

Automotive demand trends

Historically, tightening emissions legislation more than actual changes in volumes of auto sales has driven platinum and PGM automotive demand growth. Between 1990 and 2019 annual car sales rose from c.54 m to c.92 m but PGM use in autocatalysis rose from 2.2 moz per annum to 13.8 moz per annum.

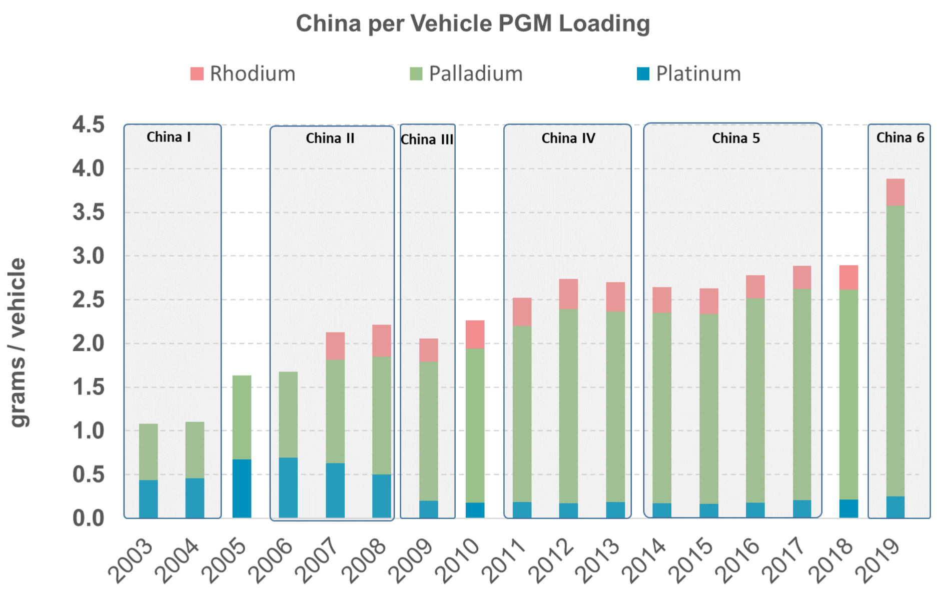
Figure 19: Total PGM autocatalyst demand growth is well above global auto sales growth over 28 years (6.2 times v 1.6 times)



Source: OICA, LMC Automotive, Johnson Matthey. Indexed chart with 1990 = 1

All major auto markets have introduced tighter vehicle emissions limits over time and significantly tighter light duty vehicle emissions legislation in recent years. The introduction that has had the biggest impact on PGM use is the China 6 standards which started being implemented in major cities in China from mid-2019. This implementation has resulted in a step change of c.40% in palladium loadings and between 50% and 100% more of rhodium. This increased demand for palladium in China and Europe has increased the likelihood of platinum substituting palladium in autocatalysts. This is where the highest demand growth in platinum is most likely to occur in the next three years. Only 5% substitution represents 450 koz.

Figure 20: China 6 implementation: step change in loadings



Source: Johnson Matthey, WPIC Research

Figure 21: Key light duty auto emissions legislation recently implemented

Region/Country	Emission	Measurement	Event	Consequences
EU	NOx	Per car	60mg / km /(gasoline) car - moving from laboratory to on-road testing 2017 / 2019	RDE on-road emissions testing: Higher loadings (+175 koz pd in 2019)
	CO_2	Fleet	95g / km / car fleet average 2020 / 2021	Annual fine of between €14.7 bn & €34 bn. Incentive to lower CO_2 via Hybrid and BEV
China	NOx, CO, HC	Per car	China 6 2020/2021 Early addoption in some cites in 2019	+ 40% Pd loadings +50% - 100 % Rh loadings Driving higher Pd and Rh prices. Incentive for substitution
North America	NOx, CO, HC	Fleet	Tier 3 / LEV III	Steady increase in palladium loadings

Source: WPIC Research

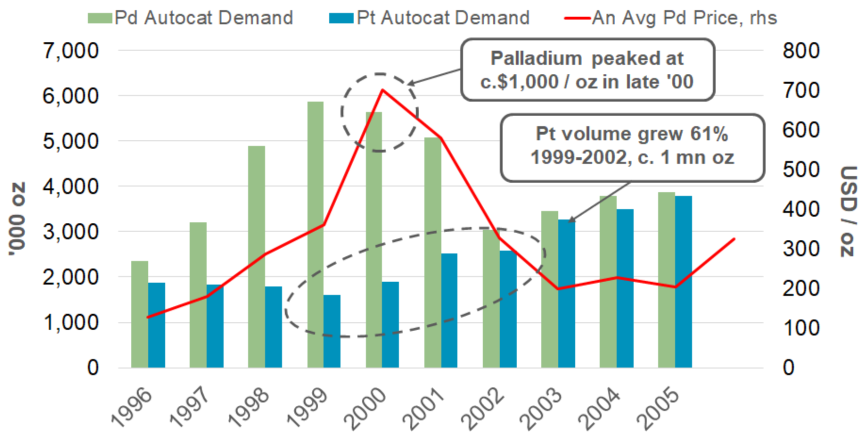
The combination of rapid auto sector driven palladium demand growth, combined with limited supply growth outlined above, suggests a re-balancing between platinum and palladium markets is highly likely.

Substitution of platinum for palladium in autocatalysts

Substitution of platinum for palladium in response to price misalignment is not a new phenomenon. The US first introduced emissions standards in 1974 which required the use of auto catalysts. This led to the use of both platinum and palladium in internal combustion engine vehicle emissions control. By the late 1990s, palladium demand consistently outstripped supply. The annual shortfall was supplied from Russian state stocks. These stocks had built up as palladium was seen as having little value or application during the early years of production from the Russian Nickel-copper mines. Much of this stock had built up almost accidentally and had been transferred to state stocks. In 2000, an administrative failure in Russia coincided with a processing failure in South Africa that resulted in palladium increasing from around $200/oz to over $1,000/oz within a few months.

The consequence of this short-term price spike to levels well above the price of platinum was substitution of palladium by platinum with a significant demand increase for less expensive platinum. As illustrated in the figure below, gross palladium usage in auto catalysts contracted by 48% between 1999 and 2002. Palladium prices quickly reduced in line with reduced demand to $260/oz by January 2003. Platinum auto catalyst usage rose by 60% over this same period.

Figure 22: Palladium and Platinum auto demand vs Price, 1996 – 2005

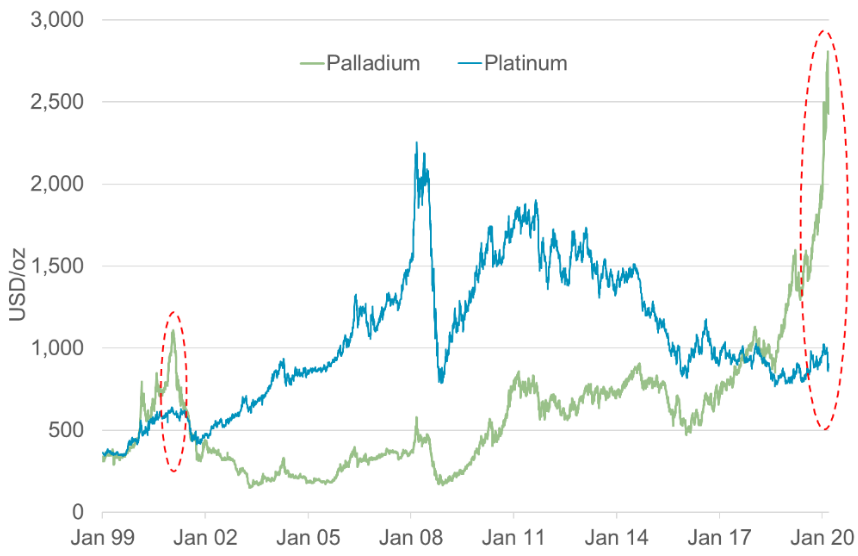


Source: Johnson Matthey, Bloomberg, WPIC Research

Until the early 2000s, twice as much palladium than platinum by mass was required to achieve similar levels of emissions reduction in gasoline engines. However, technological innovation, namely the improved stability of PGM molecules in the coating on catalysts and the significant reduction in sulphur content of gasoline, reduced this substitution ratio to the point where similar amounts of palladium or platinum can achieve the same level of emissions control. This 1:1 ratio was confirmed by Johnson Matthey in an academic paper publishing in 2013 (*A Study of Platinum Group Metals in Three-Way Autocatalysts – Platinum Metals Rev., 2013*).

Palladium is not solely used in gasoline autocatalysts. Around 700 koz of palladium per annum is used in diesel autocatalyst applications in key markets (Western Europe, North America and China). Platinum substituting palladium in diesel catalysis, the natural and long-standing home of platinum, has much lower emissions control risk than substitution in gasoline catalysis and should have a significantly shorter substitution implementation lead time. In May 2019, Johnson Matthey said it expected that platinum use in diesel autocatalysts to replace palladium could grow by tens of thousands of ounces in the short to medium term.

Figure 23: Palladium premium to platinum averaged $675/oz in 2019, and has averaged over $1,000/oz in 2020



Source: Bloomberg, WPIC Research

The economic theory of substitution suggests that manufacturers will substitute a cheaper input for a more expensive one, up to a point where it is no longer economically logical to do so. That point can be price/cost driven, as rising demand for the initially cheaper alternative drives up prices of that input or related to the impact of substitution on the performance of the output product. A substitute good is also a good with a positive cross elasticity of demand i.e., an increase in the price of one good will (all things being equal) increase demand for its substitute. Theoretically, if the prices of the goods differed, there would be reduced demand for the more expensive good.

In the case of the palladium price above the platinum price, theory suggests that where viable, more platinum should be used in automotive catalysts instead of palladium. The 1:1 substitution ratio further suggests that platinum and palladium can be viewed as almost perfect substitutes.

At the current palladium premium to platinum, and with a 1:1 substitution ratio between the two metals, there is a very strong economic argument for auto producers to substitute more platinum on future models. Palladium's current elevated price is an availability signal that also argues for PGM diversification to maintain supply chain security. Historically, sustained relative premiums (e.g., Pd over Pt) of at least 18 months or more were needed to see significant auto catalyst loadings change among the 3 PGMs (i.e., the ratios used of Pt, Pd and Rh). With no short to medium term palladium supply growth likely, the only adjustment can be via demand. The concerns of unavailability of palladium were known by OEMs and fabricators some years ago, which suggests substitution has happened on models recently launched or about to be launched. In principle, the substitutability of platinum and palladium suggests that their diverging prices should converge over the medium-term (3-5 years) as demand substitution adjusts the relative demand-supply balances.

The platinum versus palladium price chart (Figure 24) above shows palladium's overshoot in 2000 and currently as well as the change in price to reflect the change in substitution ratio from 2:1 to 1:1 between 2014 and 2017.

Jewellery demand

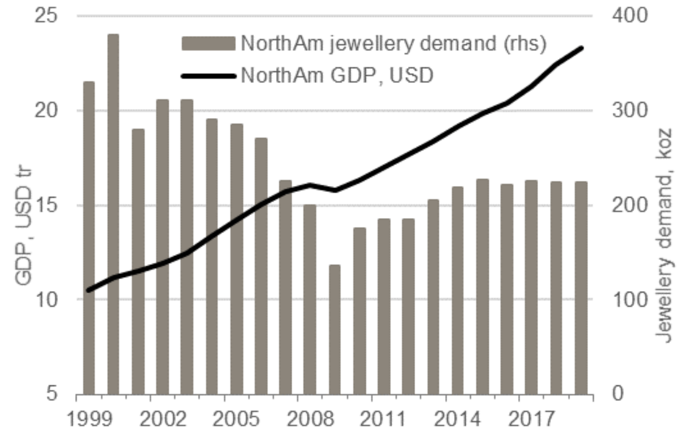
Jewellery demand trends

Gold has been used for jewellery for centuries, however, use of platinum in jewellery is relatively recent. Given platinum's precious properties are similar to (and in some cases in excess of) gold; it made sense for the platinum jewellery market to be developed. In addition, jewellery demand is more price elastic than industrial demand; this provided demand protection for producers if industrial use declined as more price elastic jewellery demand would increase. This proved crucial for producers making bold long-term mining investment decisions. Consequently, over 40 years ago, Platinum Guild International (PGI) was set up to develop the jewellery market for platinum, and is now funded by the largest platinum producers. PGI's market development resulted in annual platinum jewellery demand growing from almost zero to 2.1 moz in 2019 having peaked at over 3 moz per year. For mining companies to so substantially influence fundamental end demand of a commodity is highly unusual (and only really has a parallel in diamonds).

PGI continues to develop platinum jewellery markets; especially in emerging economies such as China and India, along with seeking to maintain / increase platinum's share of the jewellery markets in developed markets such as North America and Japan. We outline some drivers of platinum jewellery retail demand below:

1. **Economic growth** – can generate an increasing middle class with disposable income. Some of this income can be spent on jewellery and some jewellery spend can be in platinum. However, the relationship is seldom this simple, and is moderated by further factors below.

Figure 24: North America GDP (USDtr, real) vs platinum jewellery demand (thousand troy ounces, rhs)



Source: Johnson Matthey, IMF. North America = US + Canada

Figure 25: China GDP (USDtr, real) vs platinum jewellery demand (thousand troy ounces, rhs)

Source: Johnson Matthey, IMF

2. **Social changes** – traditionally, a large proportion of platinum jewellery demand is in the bridal market. A growing population can increase platinum demand on a sustainable basis (i.e. more weddings) over time; additionally, wedding seasons e.g. in China can provide a seasonal uplift in platinum jewellery demand. Conversely, an aging population, or one where the marriage rates are declining for another reason, would lead to a decline in platinum jewellery demand (all else equal).
3. **Consumer trends** – platinum jewellery exists within the luxury market, and therefore is correlated to growth in global luxury. An example of this is the boom in China luxury between 2010 and 2014; which correlated to a significant increase in China jewellery demand. Broader consumption trends can also affect platinum

jewellery demand, e.g. an increase in conspicuous consumption should lead to higher platinum jewellery demand. In recent years, there have been concerns that newer generations are more likely to spend disposable income on technology and travel / experiences, which could theoretically reduce the proportion of disposable income that would be spent on platinum jewellery.

4. **Advertising and promotion** – Where there is a growing middle class with disposable income, advertising can be very effective in stimulating platinum jewellery demand helping it to more effectively compete against other potential uses of disposable income. However, advertising in isolation of other supportive economic and social factors is unlikely to increase platinum jewellery demand.
5. **Price of platinum** (especially relative to gold) – jewellery spend is generally value rather than weight driven; i.e. if a groom is shopping for a wedding band; he likely has a specific budgeted amount; rather than e.g. specifically looking for a 5 gram wedding band. There should be a negative correlation between price and demand; so if prices fall and value spent remains constant, the demand of volume should increase. Additionally in jewellery, platinum is seen to be a premium product, with retail prices higher than that of gold. This leads to higher margins for jewellery retailers and as such, an additional incentive to offer platinum jewellery products vs gold or other jewellery products.
6. **Availability of platinum jewellery products** – the platinum jewellery market is almost ten times smaller than that of gold. This means that in many locations platinum jewellery is not available, which restricts platinum jewellery demand.

A caveat on the value chain – above we have discussed drivers of platinum jewellery retail (i.e. consumer) demand, which should ultimately determine the amount of platinum used in jewellery applications.

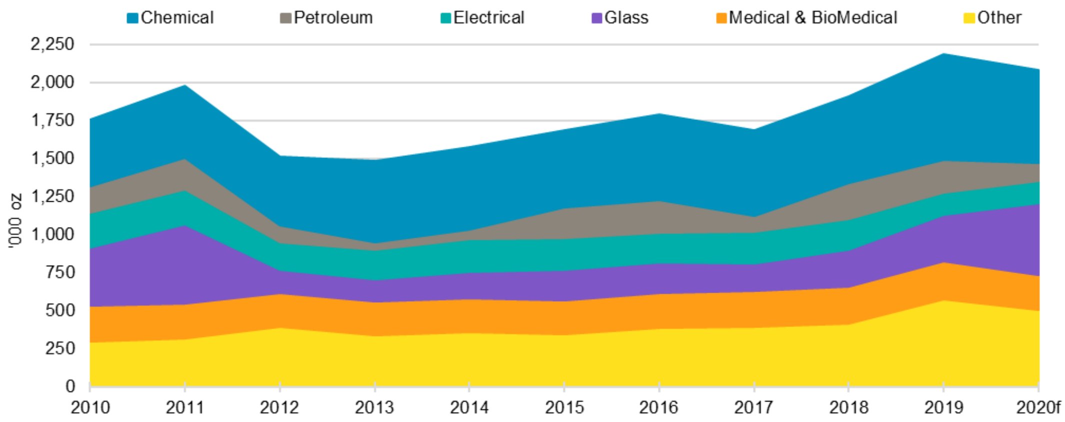
However, the jewellery value chain is complex. Inventory builds and releases at different points in the value chain can result in platinum jewellery manufacturer demand as represented in a platinum supply / demand table differing materially from platinum retail jewellery demand (though this effect should be temporary). For example, in 2016, China platinum jewellery manufacturer demand was -20% y/y, due to a reduction in inventory through the manufacturing chain. However, China platinum jewellery retail demand fell more modestly. Therefore, although in the long-term manufacturer demand should be broadly equal to retail demand, on a year by year basis there can be changes in platinum inventory that can obscure trends at the retail level. This appears to have occurred in reverse in 2020 as manufacturers in China increased stock levels at low prices caused by the COVID-19 pandemic.

Industrial demand

Given its unique physical properties, platinum has a broad variety of applications in the industrial sector (excluding automotive uses). Generally, there is a positive relationship between platinum industrial demand and global GDP. However, unlike other sources of demand, most industrial demand is represented on a net basis (i.e. the gross demand less the supply from recycled metal). Together with other factors, this makes industrial demand somewhat “lumpy”; as shown in WPIC’s Platinum Quarterly reports

Industrial demand is broken into five areas, and we give an example of platinum's use in each sub sector below:

Figure 26: Platinum industrial demand (excluding automotive) over time (000's Troy ounces)



Source: Johnson Matthey (to 2012) SFA (2013-2018), Metals Focus (2019 and 2020f), WPIC Research

Chemical – Platinum has been used in production of nitric acid for over a century. A crucial step in nitric acid production is the oxidation of ammonia gas which requires a platinum rhodium gauze. Nitric acid is needed for production of nitrogen fertilisers, which is an important source of plant nutrients.

Electrical – Platinum is used in hard disk drives (HDD); in a cobalt, chromium and platinum alloy which is the storage layer in a HDD stack.

Glass – glass is made from melting its raw materials at temperatures up to 1,700°C. Platinum alloys are used in the fabrication of vessels that hold the molten glass because of platinum's high melting point and resistance to corrosiveness. LCD glass (used in watches, laptops) is one of the most intensive uses of platinum within glass, given its requirements for thin, high quality glass with zero defects.

Medical and Biomedical – In some chemical forms, platinum can inhibit the production of living cells. The discovery of this property has led to the development of platinum-based drugs to treat a wide range of cancers. These platinum-based antineoplastic drugs are used to treat almost 50% of cancer patients. Examples include including cisplatin (shown to cure testicular cancer), nedaplatin (newer drug developed to address issues of toxicity and cancer resistance in earlier versions), and satraplatin (currently pending FDA approval).

Petroleum – In oil refining, platinum is used in reforming and isomerisation, which provides the higher-octane components needed for the production of gasoline fuel. The platinum is coated onto an alumina substrate in the form of small beads. Over time, technical developments have led to a reduction in the platinum required per unit; but this has been offset by the rise in demand for gasoline products; leaving the annual demand for platinum from petroleum fairly stable.

Fuel cells - Fuel cells have been converting hydrogen into electricity and water for over 100 years. In a platinum-based fuel cell, electricity is generated through an electrochemical reaction by combining hydrogen and oxygen, with heat and water as the only by-products. Molecules of hydrogen and oxygen react and combine using a proton exchange membrane (PEM) which is coated with a platinum catalyst, and there is no combustion.

Platinum is especially suited as the catalyst in mobile fuel cell applications as it enables the reactions between hydrogen and oxygen that take place to occur at an optimal rate, while being stable enough to withstand the complex chemical environment within a fuel cell and the high electrical current density necessary, performing efficiently over the long-term. However, unlike a battery, fuel cells do not need lengthy recharging stops to 'refuel'.

Fuel cell applications are divided in portable, mobile and stationary with different power ranges supported by different types of fuel cell (shown below).

Figure 27: Different types of fuel cells

Name	Acronym	Common uses	Industries	Operating temperature (°C)	Electrical efficiency (%)	Contains platinum?
Proton Exchange Membrane Fuel Cell	PEMFC	Portable, mobile	Road transport, Consumer	<120	up to 55%	Yes
Alkaline Fuel Cells	AFC	Stationary, mobile	Stationary power generation, space travel	<100	up to 65%	Yes
Phosphoric Acid Fuel Cell	PAFC	Stationary	Stationary power generation (100-400kW)	120-150	40%	Yes
Molten Carbonate Fuel Cell	MCFC	Stationary	Stationary power generation	600-700	up to 55%	Yes
Solid Oxide Fuel Cell	SOFC	Stationary	Stationary power generation	500-1,000	up to 60%	No

Platinum in FCEVs is currently a small, but growing, demand sector for platinum, with future demand growth coming predominantly from the heavy-duty sector, especially in the near term.

It is widely recognised that platinum-based hydrogen fuel cells offer the range and power output needed by vehicles like buses that batteries alone cannot offer. Fleets of platinum-based fuel cell electric heavy-duty vehicles are growing – and, with them, vital refuelling infrastructure.

Ambitious global CO_2 reduction targets remain on the agenda, despite the current economic setback suffered by many governments in response to the COVID-19 pandemic. Across the European Union, heavy-duty vehicles – trucks, buses and coaches – are responsible for about a quarter of all road-transport related CO_2 emissions. Last year saw the implementation of EU regulations to reduce CO_2 emissions from new heavy-duty vehicles by 15 percent in 2025 and 30 percent in 2030, compared to current emissions (measured from 1 July 2019 to 30 June 2020).

Measures such as this are providing further impetus to the growing market for zero-tailpipe emission, heavy duty FCEVs, which use a platinum catalyst as a key component. Hyundai, the South Korean automaker, is a major backer of hydrogen-powered fuel cell technology and is about to begin deployment of its H2 XCIENT fuel cell trucks in Switzerland. This initiative plans to grow the fleet of such vehicles on Swiss roads from 50 this year to 1,300 in 2023.

All FCEVs, including Hyundai's, which can travel up to 400 km without the need to refuel, have a significantly greater range than their battery-only electric vehicle (BEV) counterparts.

Fuel cells in heavy duty vehicles like trucks have a further advantage in as much as they are able to maintain a consistent power output even as the load increases, for example when carrying more weight or going up mountains - avoiding the loss of capacity and payload associated with the large heavy batteries a BEV would need if it were to fulfil a haulage function.

In North America, Hyundai has partnered with Cummins, the 100-year-old engine maker, to develop electric fuel cell powertrains for the commercial vehicle market. Elsewhere, global truck giants Daimler and Volvo are planning to work together to develop fuel cells for trucks. Their intention is to bring fuel cell trucks to the market in the second half of the decade.

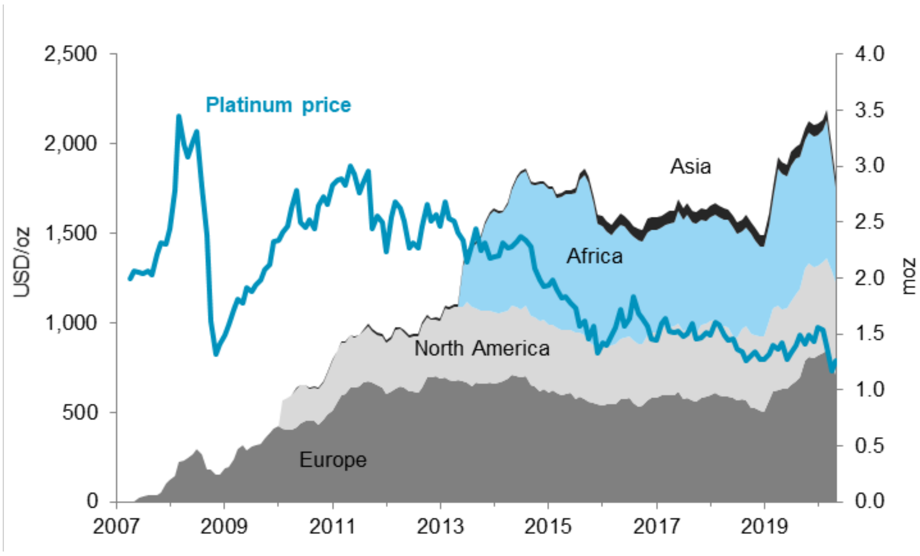
Hyundai's initiative with its partners in Switzerland brings further benefits. By combining with the food retail sector, the project will deliver a zero emissions freight solution for two of the country's leading grocery chains which will result in the roll-out of a network of hydrogen refuelling stations to, in the first instance, service the fuel cell Hyundai truck fleet.

A network of between 100 and 150 refuelling stations is expected to be in place by 2025 – infrastructure that is viable, and critically funded by the partners, as it only takes c.15 trucks per station to turn a profit as opposed to the c.700 FCEV passenger cars that would otherwise be needed.

Investment demand

Platinum good delivery bars, usually of 99.95% purity, are the form of platinum that underlies platinum trading on the London Platinum and Palladium Market (LPPM). They also underlie the NYMEX futures market; this is the form used for storage and physical investment purposes. Bars can be converted to sponge (and vice versa) at a cost, typically less than $1/oz dependent on the nature of the refinery and the opportunity cost of refining capacity at the time. Whatever the prevailing metal price, owners of one form will often swap what they own for another form at a charge approximating the conversion cost. This conversion cost or charge is often referred to as a sponge-ingot premium.

Figure 28: Platinum ETF holdings (000's troy ounces)



Platinum ETFs were created in 2007, and generally the volume of platinum invested has increased (despite a broadly downward trending platinum price).

Should investment demand be included in supply/demand analysis?

Given a commodity is a physical entity, what is represented as a "surplus" or "deficit" in a supply demand table is actually changes in inventory, whether that inventory is owned by producers, consumers or financial speculators (investors). Whilst investment demand (e.g. inventory held by speculators) has historically been included in supply demand forecasts, the view on this has changed over the past couple of years, and different financial analysts and consultancies now take varying approaches on whether to include investment demand on supply demand analysis. We outline reasons for and against including investment demand in supply demand analysis below.

Yes – Investment represents physical demand on investment, and is a potential source of supply if the investor decides to sell the metal. In this regard, it is similar to other sources of platinum demand; i.e. auto demand comes back as recycled supply once the vehicle reaches its end of life, platinum jewellery can be recycled (e.g. when the platinum price is high), with the value used toward purchase of the next piece etc.

An increase in investment demand directly affects the physical market. As an example, if there is an increase in demand for safe haven assets, there could be an increase in investment demand for platinum, which would lead to an increasing volume of platinum being bought in the market and put into a vault (in the case of a physically backed ETP). This would tighten the physical market and make it more difficult for industrial consumers to obtain metal. WPIC's approach is to include investment demand in supply demand analysis for these reasons.

No – Investors could be seen as the buyers of last resort, given neither producers nor consumers will want to hold increasing volumes of metal in an environment where the price is falling. Under this viewpoint, an increasing demand from investors does not necessarily indicate a robust underlying market, and is a potential future source of metal if the physical market tightens.

Half and Half? – A third method involves including retail investment demand but excluding institutional investment demand. The logic of this seems to be that institutional investment demand is backed by LPPM good delivery bars (ingots); if the financial instrument is sold, the underlying bar can, for example, be bought by an automaker, and converted into sponge for industrial use. If a retail investor sells a coin; the higher premium charged on the coin makes it more likely that it will be bought by another coin investor, and less likely that it will be sold to an industrial consumer, melted down, and converted into sponge for industrial use. Indeed, where the platinum coin is legal tender, it can be illegal to melt it down. Under this rationale, institutional investment demand is excluded from demand as it represents a greater risk to the physical market in the future.

Is platinum a precious or an industrial metal?

Precious metals are defined scientifically as rare, naturally occurring metallic chemical elements that hold a high economic value. They are typically less reactive and have a higher melting point than other metals, making them highly durable, ductile, and able to have a high lustre. More commonly, the notion of what qualifies a metal as "precious" is any expensive metal that may be sold as jewellery or used to make coins ─ both true for platinum.

The correlation between the prices of platinum and gold indicates its degree of behaviour as a pure precious metal while its correlation with the price of copper its behaviour as an industrial metal. These correlations have varied over time with platinum behaving more or less like a precious or industrial metal.

Figure 29: Palladium price correlations with copper and gold, and platinum premium / discount to gold (US$/oz)

		Correlation with copper (ex USD)	Correlation with gold (ex USD)	Premium / discount to gold (USD/oz)
2002-2005	Precious metal with an industrial premium	0.25	0.21	363
2006-2013	Industrial metal with a precious floor	0.36	0.55	323
2014 - 2018	Precious metal with an industrial discount	0.27	0.60	-188
2019 to date	Industrial metal with limited precious floor	0.46	0.41	-602

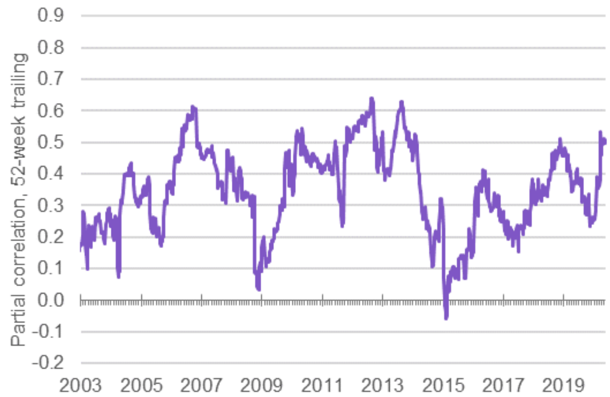
Source: Bloomberg, WPIC Research, weekly returns 11 January 2002 to 29 May 2020

As shown below, platinum has a significant and variable correlation, with both gold (most actively traded precious metal) and with copper (most actively traded industrial metal). Since 2002, the correlation in platinum returns with gold (0.48, ex USD effect) was higher than that of copper (0.33, ex USD effect) but both correlations were statistically significant (within a 0.1% probability).

Figure 30: Platinum correlation with gold (ex USD effect)

Source: Bloomberg, WPIC Research

Figure 31: Platinum correlation with copper (ex USD effect)



Source: Bloomberg, WPIC Research

Given the historical performance and the fundamental drivers of platinum, we believe it is likely that platinum will continue to trade with both precious and industrial characteristics. However, platinum's deep discounts suggest market participants are likely to respond to them, once trading recovers from the shock and reduced trading due to the initial impacts of the COVIOD-19 pandemic.

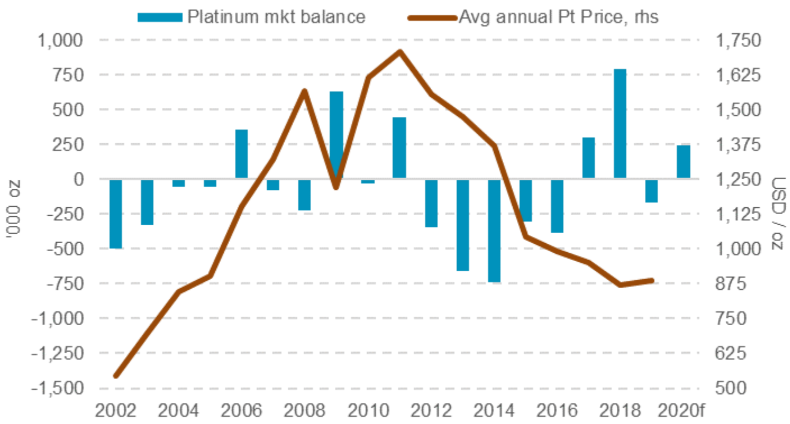
What drives the value of platinum?

Platinum market balances

Annual supply and demand of platinum has been published since 1975 by Johnson Matthey, the largest fabricator of platinum industrial products. The annual supply demand balance provides an indication of the degree of surplus or deficit in the platinum market. For all commodities, over the long term, value tends to reflect the fundamental supply demand position with prices rising on consecutive deficits and falling on consecutive surpluses. Short term prices can disconnect from these long-term trends where the degree of certainty of future market balances is high. For platinum this disconnect increased from 2012 when consecutive deficits had little impact on falling prices. Since then movements in the short-term price of platinum has been dominated by changes in positioning on the NYMEX futures market. This appears to have weakened 2020 as the impacts of the COVID-19 pandemic unfolded.

The platinum market was in a deficit in 2019, of -168 koz, driven by 985 koz of metal being purchased in the spot or OTC market to physically back the increased holdings of platinum ETFs, mainly by institutional investors. However, this relative balance occurred after 2 years of sizable surpluses in 2017 and 2018.

Figure 32: Platinum market balance, a small surplus in 2019 after 2 years of large surpluses



Source: SFA, WPIC Research

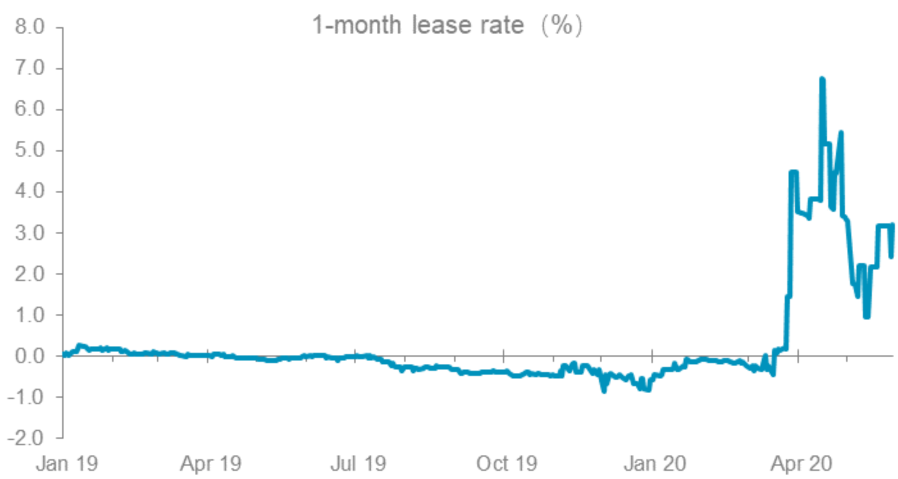
Figure 33: Platinum supply and demand table (koz)

		2015	2016	2017	2018	2019	2020f
Platinum Supply-demand Balance (koz)							
SUPPLY							
Refined Production		**6,160**	**6,035**	**6,125**	**6,120**	**6,094**	**5,287**
South Africa		4,480	4,255	4,380	4,470	4,402	3,649
Zimbabwe		405	490	480	465	455	438
North America		385	395	365	350	356	352
Russia		710	715	720	665	716	683
Other		180	180	180	170	164	166
Increase (-)/Decrease (+) in Producer Inventory		+30	+30	+30	+10	+2	+0
Total Mining Supply		**6,190**	**6,065**	**6,155**	**6,130**	**6,097**	**5,287**
Recycling		**1,705**	**1,840**	**1,890**	**1,930**	**2,165**	**1,910**
Autocatalyst		1,185	1,210	1,325	1,420	1,630	1,508
Jewellery		515	625	560	505	477	345
Industrial		5	5	5	5	58	57
Total Supply		**7,895**	**7,905**	**8,045**	**8,060**	**8,262**	**7,197**
DEMAND							
Automotive		**3,365**	**3,455**	**3,325**	**3,100**	**2,894**	**2,481**
Autocatalyst		3,230	3,315	3,185	2,955	2,894	2,481
Non-road		140	135	140	145	†	†
Jewellery		**2,840**	**2,505**	**2,460**	**2,245**	**2,100**	**1,785**
Industrial		**1,685**	**1,790**	**1,685**	**1,910**	**2,184**	**2,080**
Chemical		505	560	565	570	692	608
Petroleum		205	215	100	235	219	122
Electrical		205	195	210	205	145	141
Glass		200	205	180	245	303	478
Medical		225	230	235	240	249	229
Other		345	385	395	415	577	503
Investment		**305**	**535**	**275**	**15**	**1,252**	**605**
Change in Bars, Coins		525	460	215	280	281	605
Change in ETF Holdings		-240	-10	105	-245	991	0
Change in Stocks Held by Exchanges		20	85	-45	-20	-20	0
Total Demand		**8,195**	**8,285**	**7,745**	**7,270**	**8,430**	**6,950**
Balance		**-300**	**-380**	**300**	**790**	**-168**	**247**
Above Ground Stocks	**4140***	**2,450**	**2,070**	**2,370**	**3,160**	**3482****	**3,730**

*Source: Metals Focus 2019 – 2020, SFA (Oxford) 2013 – 2018.Notes: 1. Prior to 2019 numbers have been independently rounded to the nearest 5 koz. 2. Above Ground Stocks: *As of 31st December 2012 (SFA (Oxford)). ** 3,650 koz as of 31 December 2018 (Metals Focus). 3. Non-road automotive demand: † 2019 and 2020 included in autocatalyst.*

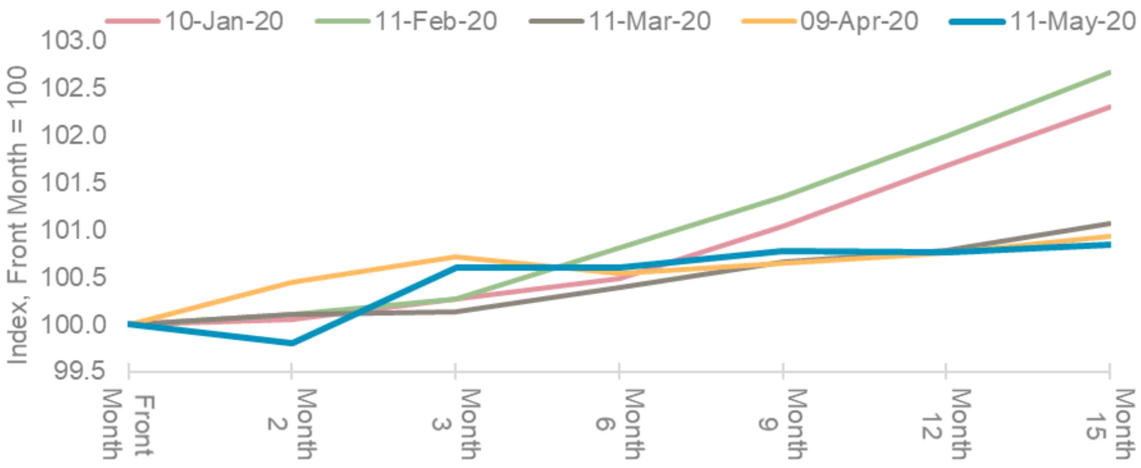
Market tightness (lack of availability of platinum) — The indications of a tight market are often reflected in higher price, increased leasing cost or the forward pricing levels or forward curve. In the first quarter of 2020 all three of the effects were visible due primarily to the impact of the COVID-19 pandemic on platinum.

Figure 34: Platinum lease rates spiked in 2020 on limited metal availability



Source: Bloomberg, WPIC Research

Figure 35: Platinum forward curve progression, backwardation on 11 May 2020



Source: Bloomberg, WPIC Research

This may well be an indication that demand growth is not yet reflected in supply demand data and most specifically the degree to which the substitution of platinum for palladium is occurring.

Demand growth potential – platinum's demand growth potential is the highest it has been in the past 5 years with three dominant components: increased diesel vehicle sales in Europe to meet reduced CO2 emissions, substitution of platinum for palladium and increased investment demand.

The most material of these is substitution. This is because the platinum and palladium markets are interlinked with regard to supply as well as demand. They are co-products or by-products in the majority of their mining locations, and they are substitutes for each other in several industrial applications, most importantly in palladium's dominant use in automotive catalysts. In this context, the market balance and resulting price movements in one metal should logically have an impact on market balance and pricing of the other. The contrast in market balances, palladium is entering its 9th consecutive deficit, suggests strongly rebalancing by substitution. We saw this mechanism in the 1990s as cheaper palladium substituted for more expensive platinum and again in reverse in 1999-2002 as palladium was replaced by less expensive platinum. A similar mechanism was observed with rhodium in 2008 when it rose to $10,000/oz and was largely replaced by palladium.

The key difference between the platinum and palladium markets today is platinum's balanced position and low price, relative to itself, gold and palladium, and palladium's sustained consecutive deficits and record high price.

How can I invest in platinum?

Financial exposure to platinum can be obtained through physical platinum like bars and coins, physically backed financial assets like ETFs, financial assets that are linked to platinum's price movements or derivatives, and assets that are affected by platinum's price movements (amongst other drivers), most notably mining equities and palladium.

Below we present examples of these platinum investment products and investments exposed to platinum. The examples provided do not constitute an exhaustive list, and costs are indicative and exclude trading related costs. The total return for an investor can also be impacted by tax implications, which are not included. An example is coins which typically have a higher premium than other investment products but may for example in a particular jurisdiction not be liable for capital gains tax. We refer investors to the disclaimer at the end of this report.

Figure 36: A range of platinum investment products (volumes and values as at 27 April 2020)

Description	**Region[1]**	**Name**	**Ticker**	**Expense Ratio (bps)**	**Assets under Management (USDm)[2]**
Physically backed					
Exchange Traded Products - ETPs[3]	Asia	Japan Physical Platinum ETF	1541 JP	50	68.2
	Europe	WisdomTree Physical Platinum	PHPT LN	49	398.6
		ZKB Platinum ETF	ZPLA SW	51	275.0
		Swisscanto Physical Platinum	JBPLUX SW	30	48.1
		UBS ETF CH-Platinum USD	PTCHA SW	35	40.6
	North America	Aberdeen Standard Physical Platinum	PPLT US	60	565.0
	South Africa	New Gold Platinum ETF	NGPLT SJ	40	644.5
		1nvest Platinum ETF	ETFPLT SJ	30	125.3
Allocated ownership of bars	United Kingdom	BullionVault		Fees c~1%[4]	39.1
Physical					
Description	**Country**	**Name of Product**		**Premium**	**Sales tax**
Bars[5]	United States	Valcambi 1oz		13%	State dependent[6]
		Credit Suisse 10oz		15%	
	United Kingdom	Valcambi 1oz		17%	20%[7]
		Royal Mint 1kg		14%	
	Singapore	Valcambi 1oz		13%	0%
		Valcambi 1kg		12%	
Coins[8]	United States	Platinum Maple Leaf (Canada)		17%	State dependent[6]
		Platinum American Eagle (US)		22%	
	United Kingdom	Platinum Queen's Beast (UK)		31%	20%[7]
		Platinum Maple Leaf (Canada)		15%	
	Singapore	Philharmonic Platinum (Austria)		19%	0%
		Platypus Platinum (Australia)		19%	
Assets affected by platinum price					
Description	**Region**	**Entity**	**Ticker**	**Market Cap (USDm)[9]**	**Platinum % revenue (2019)[9]**
Equities	South Africa	Anglo American Platinum Ltd	AMS SJ	14,463	30%
		Impala Platinum Holdings Ltd	IMP SJ	4,974	31%
		Northam Platinum Ltd	NHM SJ	2,699	31%
		Royal Bafokeng Platinum Ltd	RBP SJ	493	38%
		Sibanye Stillwater Ltd	SSW SJ	5,628	32%

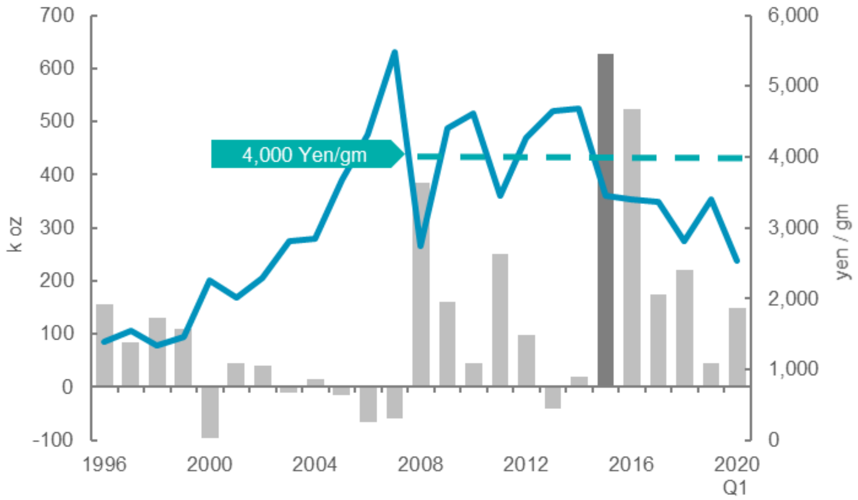
Source: Bloomberg, WPIC Research, BullionVault, goldsilvercentral.com, apmex.com, royalmintbullion.com, jmbullion.com. Notes: 1. Denotes the region the financial product is listed in, rather than where investors are domiciled. 2. AuM as at 27th April 2020. 3. ETPs included which have holdings over 5koz of platinum. 4. Bullion Vault Fees include 0.5% commission and 0.48% storage and insurance fees. 5. Bars are minted only, with premiums calculated based on price of a bar (on a per oz basis) vs spot platinum price at 27th April 2020. 6. US sales taxes on platinum bars / coins dependent on the state they are sold from; many states apply 0 tax. 7. VAT only becomes payable on physical delivery, with bars and coins held in the Royal Mint's vault VAT-free. 8. Coins shown are 1oz 2019 editions except where noted. Premiums are calculated based on purchase of a single coin vs spot platinum price at 27th April 2020. 9. As at 27th April 2020. 10. Based on reported revenues for financial year 2019.

Physical investments

Physical platinum investments exist across a spectrum from bullion products to collectible products, with the latter having higher premiums. Bars and coins are examples of physical investments. The positives are that the investor gains direct price exposure and has physical possession of the asset. The negatives are platinum bars are often liable for sales taxes (unlike gold coins). Coins and bars also often attract storage and insurance fees. Platinum coins and small bars are harder to produce than gold and silver, given platinum's more complex casting requirements relative to gold and an established infrastructure that is optimised for gold and silver; less so for platinum. Historically, premiums were high for platinum but in recent years platinum investment products offered (many by WPIC partners) are much closer to those of gold and silver investment products. These premiums can be further reduced by purchasing higher volumes.

The secondary market for platinum bars and coins is less developed in some regions. Nevertheless, where there is an established market, the demand for platinum bars and coins is robust, with Japanese investment demand responsive to dips in the domestic platinum price. Investors have responded materially to dips below 4,000 yen per gram, but in recent years — despite weaker price — demand has continued to respond to dips.

Figure 37: Japan platinum bar and coin demand (thousand troy ounces) vs platinum price (yen per gram)



Source: Bloomberg, Johnson Matthey, Metals Focus, WPIC Research

Physically backed investments

Platinum Exchange Traded Funds (ETFs) — provide direct price exposure, and easy re-sale (given their exchange traded nature). The listings requirements for ETFs are specific to the exchange on which they are listed. Most require that when a new share in a platinum ETF is issued the issuer has three days to purchase platinum bars (in the OTC market) and store them in a vault. There are typically no sales type taxes on ETFs and no separate insurance or storage costs but there are management fees between 0.35% and 0.75%. However, financial ownership of the ETF does not necessarily confer the right to take possession of the physical platinum.

Figure 38: A range of platinum ETFs (volumes and values as at 27 April 2020)

Region	Fund	Country	Inception	Ticker	Management fee (%)	Current Oz	Value (USD mn)	% of total
Asia	ETFS Metal Securities Australia Ltd - ETFS Physical Platinum	AU	30/01/2009	ETPMPT AU Equity	0.49	5,312	4	0%
	Japan Physical Platinum ETF	JP	02/07/2010	1541 JP Equity	0.59	92,281	78	3%
	Total Asia					**97,592**	**82**	**3%**
Europe	iShares Physical Platinum ETC	GB	11/04/2011	IPLT LN Equity	0.00	56,155	47	2%
	Invesco Physical Platinum ETC	GB	14/04/2011	SPPT LN Equity	0.39	16,976	14	1%
	WisdomTree Physical Platinum	GB	24/04/2007	PHPT LN Equity	0.49	497,267	419	17%
	Xtrackers Physical Platinum EUR Hedged ETC	DE	26/07/2010	XAD3 GR Equity	0.75	156,920	132	5%
	Xtrackers Physical Platinum ETC	GB	22/07/2010	XPLA LN Equity	0.45	44,605	38	1%
	Swisscanto ETF Precious Metal Physical Platinum	CH	06/01/2010	JBPLUX SW Equity	0.30	59,582	50	2%
	UBS ETF CH-Platinum	CH	10/09/2010	PTCHA SW Equity	0.35	52,362	44	2%
	ZKB Platinum ETF	CH	10/05/2007	ZPLA SW Equity	0.50	365,311	308	12%
	Total Europe					**1,249,179**	**1,052**	**41%**
North America	Aberdeen Standard Physical Precious Metals Basket Shares ETF	US	22/10/2010	GLTR US Equity	0.60	25,298	21	1%
	Aberdeen Standard Physical Platinum Shares ETF	US	08/01/2010	PPLT US Equity	0.60	756,677	637	25%
	Sprott Physical Platinum & Palladium Trust	US	19/12/2012	SPPP US Equity	0.50	22,686	19	1%
	GraniteShares Platinum Trust	US	22/01/2018	PLTM US Equity	0.50	10,350	9	0%
	Total North America					**815,011**	**686**	**27%**
South Africa	1nvest Platinum ETF	ZA	07/04/2014	ETFPLT SJ Equity	0.30	120,375	101	4%
	New Gold Platinum ETF	ZA	26/04/2013	NGPLT SJ Equity	0.40	729,194	614	24%
	Total South Africa					**849,570**	**715**	**28%**
						3,011,352	**2,536**	

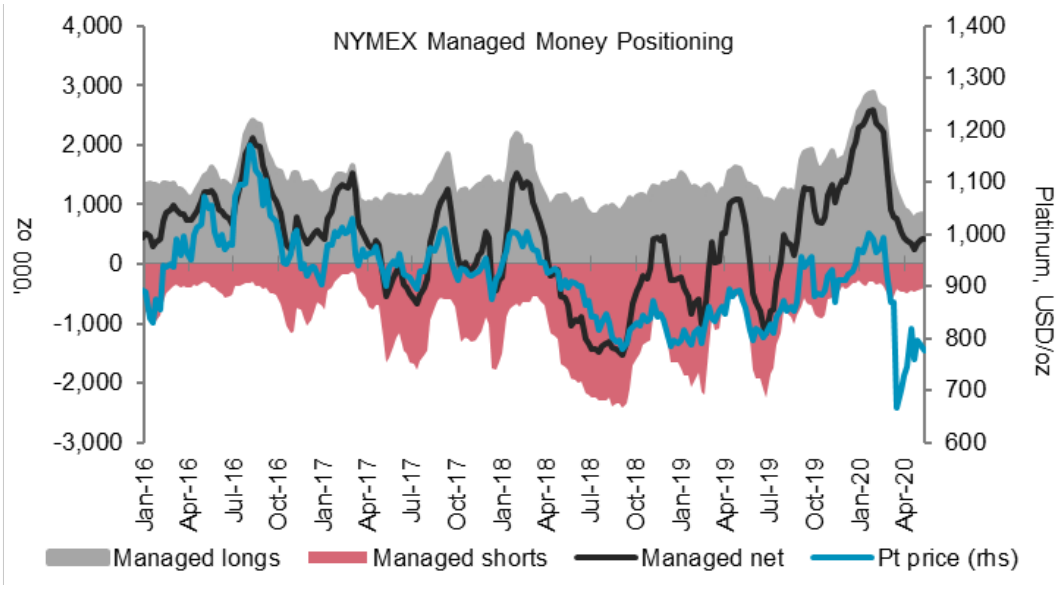
Source: Bloomberg, Respective ETP providers, WPIC research, as at 30 April 2020

Online vaulted platinum — There are services that offer allocated ownership of physical platinum. Typically, allocated ownership in platinum has meant physical delivery and possession which has meant higher premiums, commissions, insurance costs and taxes for the investor. Investors can also now take allocated ownership of platinum, vaulted on behalf of the investor without taking physical delivery, avoiding associated costs.

Investments directly linked to the platinum price

Futures — Investor exposure to platinum can also be achieved by buying a platinum futures position. Platinum futures are standardised, exchange traded contracts, in which the buyer agrees to take delivery from the seller, a specific quantity of platinum. Although the contract is theoretically for settlement of physical metal; in practice a very small amount of futures positions results in delivery of the underlying metal; instead traders are more likely to trade or cash settle their futures contracts before they mature. Platinum futures listed on the CME cover a period of 13 months, beginning with the current month, the next two calendar months and moving into the quarterly cycle of January, April, July and October. One NYMEX futures contract is for the purchase or delivery of 50 troy ounces which at $800/oz is a value of $40,000 and is typically used by large institutional investors and industrial users of platinum.

Figure 39: NYMEX platinum futures long, short and net positioning (000's oz), platinum price (US$/oz)



Source: CFTC, NYMEX, WPIC Research

Futures have some peculiarities compared to other ways of investing. Firstly, only a fraction of the value of the investment is required when buying or selling, known as the initial margin. This fraction can be as low as 5%, which entails a leverage of 20 times the initial stake. Secondly, futures have a finite maturity, so to avoid owning the future past the maturity of the contract, an investor needs to roll into the next available contract (sell the old one and buy the new one). As the futures curve for platinum is usually upward sloping (prices are higher further into the future), this implies rolling from a cheaper contract into a more expensive one to maintain the same exposure. Over time, this 'rolling' incurs a cost and reduces investor return.

Cash settled accounts — Investors in China can obtain exposure to platinum through platinum trading accounts. These are available through commercial banks in China.

Investments significantly affected by the platinum price

An example of investments effected by the platinum price are equities of mining companies that produce PGMs. Here platinum historically comprised up to 60% of mining revenues. However, there are other significant drivers of the value of these mining equities, including the price of other PGMs and metals contained in the same ore mined (e.g. palladium, rhodium, gold, copper and nickel); the exchange rate in the mining region (e.g. RUB and ZAR); operational performance including costs and efficiency; and the associated social, regulatory and environmental risk of mining companies. In recent years the high price of palladium and rhodium reduced platinum revenue to South African PGM mining companies to c.30% in 2019.

WPIC aims to increase investment in platinum

World Platinum Investment Council (WPIC) was established by the leading South African PGM miners in 2014 to increase investment ownership in platinum. This is done through both actionable insights and targeted development. We provide investors with the information to support informed decisions e.g. the *Platinum Quarterly* and monthly *Platinum Perspectives* and *Platinum Essentials*. We also analyse the platinum investment value chain by investor, product, channel and geography and work with partners to enhance market efficiency and increase the range of cost-effective products available to investors of all types. In addition, the established links between our partners and their clients amplify the distribution of WPIC research and insights and contribute to meeting the research and insight needs of the growing pool of investors actively considering an investment in platinum. We have a strong pipeline of new partners and products that will assist in enhancing awareness and distribution of platinum in 2020 and beyond.

How has an investment in platinum compared to other assets over time?

We show the real annual returns of platinum relative to other asset classes below. This demonstrates that over the long term, platinum returns are comparable to other assets typically owned by investors and included in many portfolios. Platinum may be suited to far more investor portfolios than currently include it.

Figure 40: Platinum annual returns over time

1991-1996	1996-2001	2001-2006	2006-2011	2011-2016	2017-to date*
Macro HF (21%)	Equity HF (19%)	EM equities (27%)	Gold (20%)	Private equity (19%)	Gold (47%)
Equity HF (21%)	Private equity (14%)	Global real est. (27%)	Oil (12%)	DM equities (11%)	DM equities (27%)
Global real est. (14%)	Macro HF (11%)	Oil (25%)	US fixed income (7%)	Global real est. (10%)	US fixed income (18%)
EM equities (13%)	DM equities (7%)	Platinum (19%)	Macro HF (5%)	Equity HF (5%)	EM equities (17%)
DM equities (11%)	US fixed income (7%)	Gold (18%)	Platinum (4%)	US fixed income (2%)	Private equity (14%)
Commodities (11%)	Global real est. (5%)	Commodities (16%)	EM equities (3%)	EM equities (2%)	Macro HF (5%)
US fixed income (7%)	Platinum (3%)	DM equities (10%)	Equity HF (1%)	Macro HF (1%)	Equity HF (5%)
Oil (6%)	Commodities (2%)	Private equity (10%)	DM equities (-2%)	Gold (-6%)	Global real est. (0%)
Platinum (1%)	Oil (1%)	Macro HF (9%)	Commodities (-2%)	Platinum (-8%)	Platinum (-13%)
Gold (1%)	EM equities (-4%)	Equity HF (9%)	Global real est. (-5%)	Commodities (-9%)	Commodities (-27%)
	Gold (-5%)	US fixed income (5%)	Private equity (-12%)	Oil (-12%)	Oil (-56%)

Source: WPIC Research, Bloomberg (30 April 2020)

What are the ESG considerations for investing in platinum?

Mining in South Africa has a socially and politically complex history, given many mining activities were started far in advance of South Africa's first democratic election in 1994.

The preceding six decades excluded large portions of the population from the economic benefits of mining the country's natural resources. Since 1994 South Africa has undergone many positive social and political changes, which has been reflected in changes to the mining industry. A significant aim of the democratically elected government was for the proceeds of mining to be more equally shared between South Africa's populace. Much progress has been achieved.

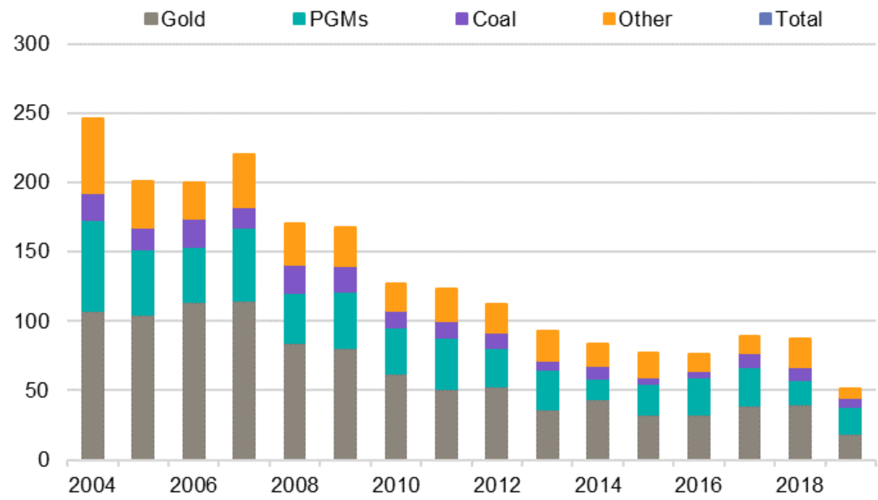
Fatalities and safety

South Africa's ore deposits entail a very high degree, by global standards, of conventional mining requiring high numbers of workers. Hard-rock, narrow-seam underground mining has potentially hazardous environments. Mines can operate up to 5km underground (though platinum mines are usually less than 1.5km deep) with rock temperatures reaching 60ºC. Due to these challenging operating conditions, health and safety of all workers in the mining environment are key priorities. The most common causes of fatalities are falls of ground (rockfalls), followed by transport related injuries.

South Africa's Mine Health and Safety act was introduced in 1996 and there has been a combined effort between mining companies, employee unions and the government to jointly promote a safe and healthy working environment. Since 2004, the number of fatalities in South Africa's mining industry has reduced by 80%.

South African mining fatalities by commodity (2004-2019)

Figure 41: South African mining fatalities by commodity (2004-2019)



Source: Minerals Council South Africa

Water use

Water is an essential component in the mining industry, it is used for mineral processing, dust suppression, material transportation and employee requirements. Within the mining operations, mineral processing and tailing dams consume the most amount of water. Evaporation from the tailings storage facilities and entrainment losses during tailings discharge are dominant contributors to water consumption.

The use and impact of water can result in a range of environmental, social and economic risks. Mining companies take an active role in conserving and managing water use, as not doing so can affect the availability and quality of water for local communities; ultimately impacting the miners' licence to operate from a social and a regulatory perspective.

Benefits in end use

Each year 36-43% of the world's platinum is used in the automotive industry. In catalytic converters, PGMs are used in the exhaust system where they act as a catalyst to reduce harmful emissions. If the engine exhaust gases were not treated it would have been unlikely that society would have benefited from the increase in global mobility over the past decades.

The global transition from internal combustion engine (ICE) vehicles to electric vehicles will take at least 15 to 30 years. During that period, the remaining portion of ICE vehicles on the road needs to be as CO_2 efficient as possible. Platinum Group Metals (PGMs) have an important strategic role in the long-term decarbonisation of primary power generation and transport. They are also able to facilitate mandatory reductions in CO_2 emissions from internal combustion engines that legislators have imposed to manage the transition away from fossil-fuel reliance. The COVID-19 pandemic may have increased the importance of their role.

Platinum's role in autocatalysts is already underway. For example, a diesel mild-hybrid vehicle with a platinum autocatalyst (non-plug in and with regenerative energy storage that is not driver controlled) has c.35% lower CO_2 emissions than a conventional gasoline vehicle. Similarly, palladium is being used to catalyse gasoline mild hybrid vehicles which are part of the power train mix – despite not being as CO_2 efficient as a diesel mild hybrid.

PGMs not only enable improved emissions control during the transition, but are also a fossil-free solution in their own right. The platinum-based proton exchange membrane (PEM) fuel cell is ideally suited to mobile vehicle applications due to its small size and high electrical power capacity. It means that electric vehicles can be powered by hydrogen, providing a zero-tailpipe emissions vehicle that reduces long-term reliance on fossil fuels. Fuel cells also facilitate growth in the renewable portion of primary power generation enabling electricity to be stored as hydrogen. Increasing renewable power generation in turn reduces the CO_2 impact of recharging battery electric vehicles (BEVs), making it easier to secure the most CO_2-efficient mix of BEV and FCEV vehicles in short- and long-range applications respectively.

Social impact

The PGM industry is an important element of the South African economy. It is a significant employer, with 164,500 direct employees in 2019; with each mine employee estimated to support a further 5-10 people. It provides numerous development benefits to the surrounding communities through company sponsored programs. Overall benefits include employment opportunities, housing, health monitoring and creation of procurement opportunities. Mining companies also collaborate with the government. On improvement to roads, schools, sanitation electricity and water supply.

Good labour relations are key to effective mining operations and underscores the importance of a positive and productive working relationship between miners, employees and local communities. The Minerals Council South Africa plays a key role in achieving this; https://www.mineralscouncil.org.za/

Glossary

3E – 3 Elements, total content of platinum, palladium and rhodium

4**E** – Total of platinum, palladium, rhodium and gold

5E – Total of platinum, palladium, rhodium, iridium and ruthenium

6E – Total of platinum, palladium, rhodium, gold, iridium and ruthenium

Alluvial – An ore deposit that is in a current or old riverbed

Bushveld Igneous Complex – a large layered, saucer shaped, body of metal containing rock, approximately 500km wide and with depths over 2,000m formed through the cooling and solidification of a volcanic lava intrusion, north west of Johannesburg in South Africa. It is rich in Platinum Group Metals

By-product – In mining, a metal that contributes much less in revenue than the primary metal produced at the mine. In mining also known as a co-product

Concentrate – The product of mineral processing that is a higher grade than the ore that contains valuable minerals recovered by froth flotation

Deposit – A collection of ore that is contained in an area

Grade – A measure of concentration indicating how much valuable metal is contained ore. In PGM mining, grade is often commonly referred to as grams of 4E (platinum, palladium, rhodium and gold) content per tonne of ore (g 4E/t)

koz – thousand troy ounces – equivalent to 31.103 kilograms

Matte – A layer of valuable minerals produced through smelting. In the case of platinum smelting it is enriched with platinum group metals

Merensky reef – Layer of the Bushveld Complex supplying PGMs, and yields significant quantities of copper, nickel, cobalt and gold as by-products. It is mined on both the eastern and western limbs of the Bushveld Complex

moz – million troy ounces – equivalent to 31.103 metric tonnes

Open pit – A type of mining operation whereby ore extraction is from the surface without the use of shafts

Ore – Raw material in the earth's crust that contains a valuable mineral or metal. With the exception of coal and steel raw materials, most ores are further processed to produce the material for sale or for trading

Platinum Guild International (PGI) – Platinum Guild International (PGI) is a marketing organisation created to develop the global platinum jewellery market as a demand source for platinum. Founded in 1975 and currently funded by leading South African platinum producers with co-funding of programmes from the jewellery industry. Since 2015 PGI is based in Hong Kong supporting the four main platinum jewellery markets of China, Japan USA and India

Platinum Group Metals (PGMs) – A group of metals commonly present with platinum in platinum bearing ore. Can refer to some or all of platinum, palladium, rhodium, iridium, ruthenium and osmium. Commonly, measures of PGMs exclude osmium, which is also a PGM, but is discovered in quantities too small to make a meaningful economic contribution, is usually not assayed and is highly toxic. Measures of PGMs also commonly include gold given its co-occurrence with PGMs

Platreef – Ore body of the Bushveld Complex on the northern limb. It is a different nature of rock due to magma in this region reacting with the lime rich floor rocks. It is the third largest PGM deposit, after Merensky and UG2 with different metal ratios and much higher base metal content

Powertrain – used to describe the type of components in a vehicle that generate the power that is delivered to the road surface. Usually used to refer to the engine or electric motor and the transmission and various combinations thereof

Prill split – ratio of Platinum Group Metals

Reef – A regularly shaped and lengthy occurrence of a mineral or metal in an ore body

Reserves – a measure of the volume of valuable material (e.g. platinum, gold, oil etc), that can be mined or extracted from an ore body, and provide an adequate commercial return to the operator, given a certain set of assumptions on technological capabilities, commodity prices, foreign exchange rates, and other variables. Commonly reported in annual reports of extractive companies (e.g. mining, oil). It includes losses that are expected to occur when the material is mined

Shaft – a narrow vertical or inclined hole or tunnel blasted or drilled into the earth to provide access for men, material or ventilating air to an ore body

Troy ounce – Traditional unit of weight used to measure precious metals, equivalent to 31.103 grams (compared to a normal ounce which is 28.349 grams)

UG2 reef – Upper Group 2, layer of the Bushveld Complex, usually 20-400m below the Merensky Reef with lower PGM grades but a richer chromite content

ZAR – South African Rand

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