

WATTS, J.C., FORREST, S.A., CLARKE, B. and ATILAN, O. Future shifts in PGM demand—the impact of technological and economic scenarios on future metal demand. *Third International Platinum Conference 'Platinum in Transformation'*, The Southern African Institute of Mining and Metallurgy, 2008.

Future shifts in PGM demand—the impact of technological and economic scenarios on future metal demand

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In this paper we will examine the effect of several technological, legislative and economic scenarios on the future demand for platinum, especially in the autocatalyst sector. SFA Oxford has constructed a number of scenarios to model the impact of a wide range of influences on the demand for platinum out to 2016.

The central case is our most likely outcome for the market, built on supply/demand fundamentals, producer economics for mine closure and project inducement. Given the importance of crude oil prices in terms of influencing global growth, our optimistic and pessimistic scenarios are based on a range of crude oil prices, and their resultant effects on GDP.

Next, we consider the effect on platinum demand of the roll-out of ever more stringent automotive emissions legislation. This covers the main vehicle classes in each region of the world. Our new technologies scenario examines the effects on platinum demand, which are expected to occur with the staggered introduction of new automotive technologies—including cleaner diesel, diesel-hybrids and fuel cells—designed to improve vehicle fuel efficiency and minimize environmental damage.

Introduction

Global platinum demand is forecast to grow from 8 270 koz in 2008 to 9 690 koz in 2012. Going forward, autocatalysts remain the mainstay of PGM demand, making up a steady 56% of platinum usage. Jewellery's share of platinum demand will decrease slightly from 19% to 18% between 2007 and 2012, though total ounces consumed in jewellery are expected to increase 10% over the same period.

Price-induced substitution, jewellery elasticity and increased recycling fail to ease market tightness in the short to medium term. Autocatalyst demand rises strongly into 2009 as several countries prepare for and adopt major upgrades to emissions legislation. This effect is now slightly less pronounced than at previous new legislation steps as palladium continues to be substituted for platinum in both gasoline and diesel autocatalysts. Annual platinum demand jumps some 14% from 2008 to 2009, then levels off as thrifting takes place. Jewellery remains the shock absorber of the market as high platinum prices negatively affect demand (rising platinum prices could result in a drop in consumption across all regions of more than 150 koz in 2008). Historically high prices are expected to take significant amounts out of the platinum jewellery market each year from 2008 to 2012.

Autocatalysts also account for the greatest share of palladium consumption. Autocatalyst demand currently equates to some 59% of end-use demand and palladium's price differential to platinum drives substitution in both gasoline and diesel engines. Global palladium demand has grown from 3 410 koz in 1990 to 8 340 koz in 2007, an average 6.0% growth year on year, and is forecast to rise from 8 570 koz in 2008 to 10 170 koz in 2012. Palladium demand accounts for 46.8% of global 3E PGM consumption.

Demand for palladium in autocatalysts grew by 10% year on year in 2007 to 4 929 koz. An encouraging outlook for palladium usage in this sector is forecast as emerging economies become the largest vehicle producers. With Chinese car production growth of 11% p.a. predicted over the next ten years and China favouring gasoline combustion technology over diesel, the growing use of palladium-rich catalysts will contribute significantly to demand. This, in combination with the continued tightening of emissions legislation worldwide, particularly with Euro V legislation being promulgated in 2009, will ensure that demand growth in the more mature consumer markets continues.

Autocatalyst demand is projected to rise some 20% between 2008 and 2012 and autocatalysts should remain the mainstay of palladium demand over the next ten years, making up a steady 60% of consumption.

The rhodium market is small, readily manipulated by suppliers and expected to remain tight. It is predicted to remain in deficit until 2012 from strong demand growth, particularly in the autocatalyst sector and from China; any further disruptions to supply will continue to evoke price volatility.

Through rhodium's principal use as a partner to platinum and palladium in autocatalysts, demand will grow from 1 210 koz in 2008 to 1 420 koz in 2012. Autocatalysts are expected to maintain their 89% share of rhodium consumption going forward. Other applications of rhodium (glass manufacture, chemical catalysis and electronics) are forecast to shift rhodium demand some 23% from 2008 to 2012.

The tight rhodium market is encouraging fabricators to thrift-in cheaper palladium for rhodium. Carefully managed producer marketing initiatives will improve rhodium consumption and will ensure the market stays closely

balanced. Nonetheless, with prices above \$9 000/oz through 2008, efforts are being redoubled by autocatalyst fabricators to thrift-in palladium for rhodium in NO_x reduction applications.

Scenarios

SFA has constructed a number of scenarios to examine a wide range of possible influences on future PGM demand. In order to produce a varied and thorough examination of the potential future directions of PGM demand, we have constructed distinct scenarios based on what we consider to be the most likely influences. The SFA outlook is the central case outcome for the market, and takes cognisance of supply/demand fundamentals, and producer economics of mine closure and project inducement. Our extended legislation scenario takes cognisance of the potential effects on PGM demand that could result from a continuing rolling out of increasingly stringent vehicle emissions legislation. (Figure 1.) This is combined with our new technologies scenario (Figure 1) that examines the effects on PGM demand that are expected to occur with the staggered introduction of anticipated new automotive technologies (cleaner diesel, diesel-hybrids) designed to improve and increase vehicle fuel efficiencies. Finally, we present a scenario based on the lasting fall-out from the recent credit

crunch, called the global economic slowdown scenario (Figure 2).

New technologies scenario

New technologies scenario (including extended emissions scenario): vehicle propulsion technology changes and market penetration. The need to reduce vehicle CO₂ emissions is driving the development and adoption of new technologies. Over the short to medium term, clean diesel, and diesel and gasoline hybrid engines are expected to gain a larger share of the market. Over the medium to long term (beginning approximately in 2020), polymer electrolyte membrane (PEM) fuel cells are forecast to gain commercial-scale adoption in vehicles. The new automotive technologies will substantially affect PGM supply/demand balances, with platinum demand increasing by almost 19% by 2012, keeping the market in deficit. The influence of the current credit crunch on demand, whereby global economic growth is reduced by 0.5% in the next two years, could move the market back into surplus a year earlier than the central case in 2010 as demand in all sectors is reined in.

PGM demand—trends and drivers

Demand for platinum, palladium and rhodium is dominated by offtake in the autocatalysis sector and this is forecast to

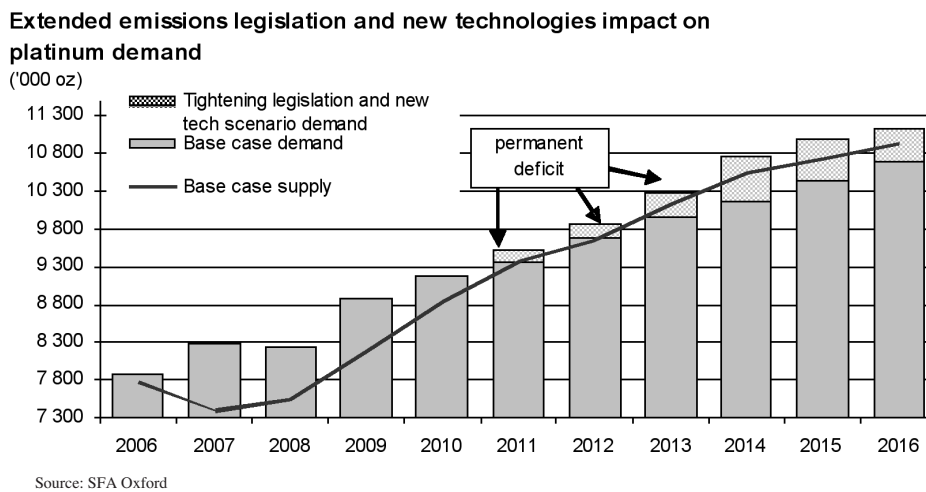


Figure 1. Effect on platinum demand of tightening emissions legislation beyond 2010 and aggressive uptake of new automotive technologie

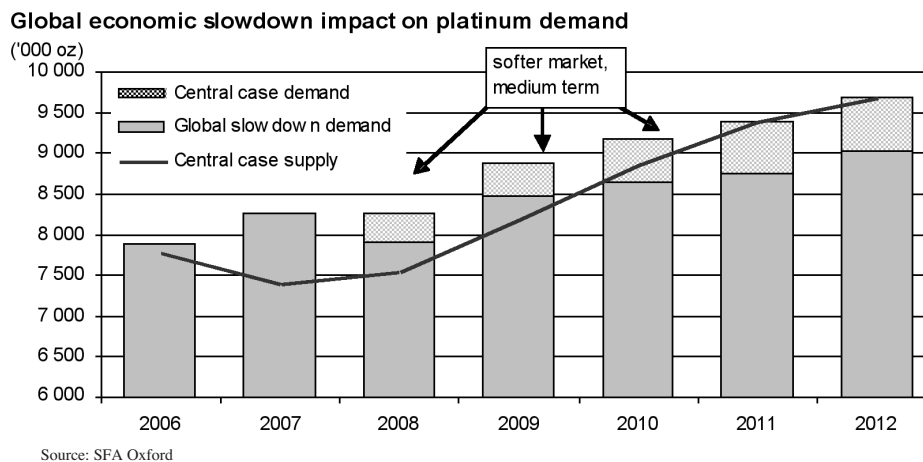


Figure 2. Effect on platinum demand of global economic slowdown

continue. Jewellery remains the second major use for platinum, and though an important market for palladium, has been displaced by uses in the electronics sector. In the following sections, we consider the underlying drivers of demand behaviour in autocatalysis and jewellery for platinum, palladium and rhodium.

- Global platinum demand is forecast to grow from 8 270 koz in 2008 to 9 690 koz in 2012, an average of 4.1% per year.
- Global palladium demand is forecast to grow from 8 570 koz in 2008 to 10 170 koz in 2012, an average of 4.4% per year.
- Global rhodium demand is forecast to grow from 1 210 koz in 2008 to 1 420 koz in 2012, an average of 4.2% per year. (Figure 4.)

Autocatalysts

Autocatalyst offtake makes up around 56% of global platinum demand and is forecast to remain at this level out to 2012. Autocatalyst demand for palladium is a slightly higher fraction, steady at around 59% of global demand. The rhodium demand profile is dominated by the autocatalyst market, again, steady at around 89%.

As with the development of gasoline engines, palladium is now successfully being substituted for some of the platinum in diesel autocatalysts. A 10% infiltration of

palladium in diesel catalysts is estimated to result in a 380 koz increase in demand, while platinum demand falls by a similar amount. Demand forecasts are based on palladium comprising up to 18% of diesel autocatalysts in Europe by 2018 and in China by 2020. The diesel vehicle market share in Europe has also increased from around 46% of light vehicles to around 52%.

Autocatalyst consumption will continue to dominate the palladium market, with electronics demand remaining ahead of usage for jewellery. Autocatalyst demand for palladium grew by 10% year on year in 2007 to 4 929 koz. This is projected to rise to 5 039 koz, a 2.2% increase, in 2008 and by 21% by 2010 to 5 947 koz.

Palladium autocatalyst demand is highest in the gasoline dominated USA (36% of global demand). Palladium demand will be strongest in regions such as China, India, Russia and South America which have the fastest growth in light vehicle production. These regions have ambitious targets to catch up with the highest standards of emissions control.

As ultra-low sulphur diesel availability increases and sulphur levels continue to fall, so more palladium can be used in diesel catalysts—traditionally a platinum-rhodium only end use.

Expected legislation tightening has raised the forecast infiltration of palladium in diesel autocatalysts at the expense of platinum. Emissions legislation has become

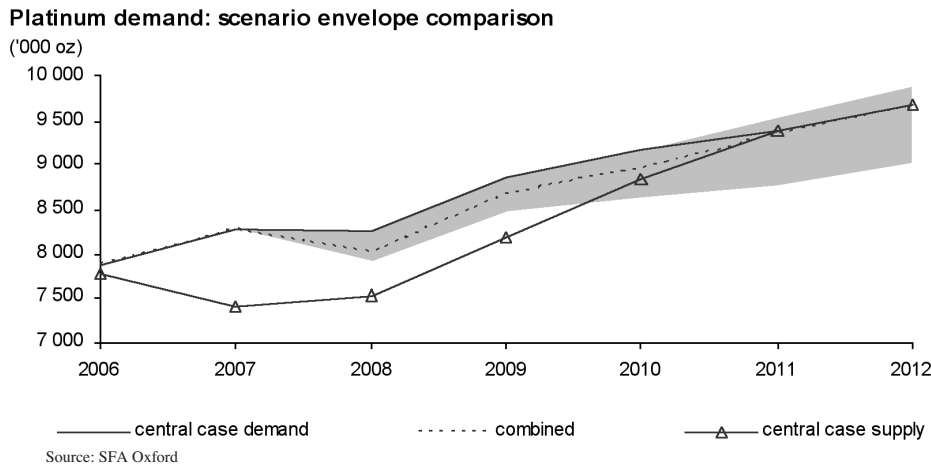


Figure 3. Scenario envelope (in grey) highlighting the upside and downside risks to forecast demand with the combined scenario indicating most likely risks to the market

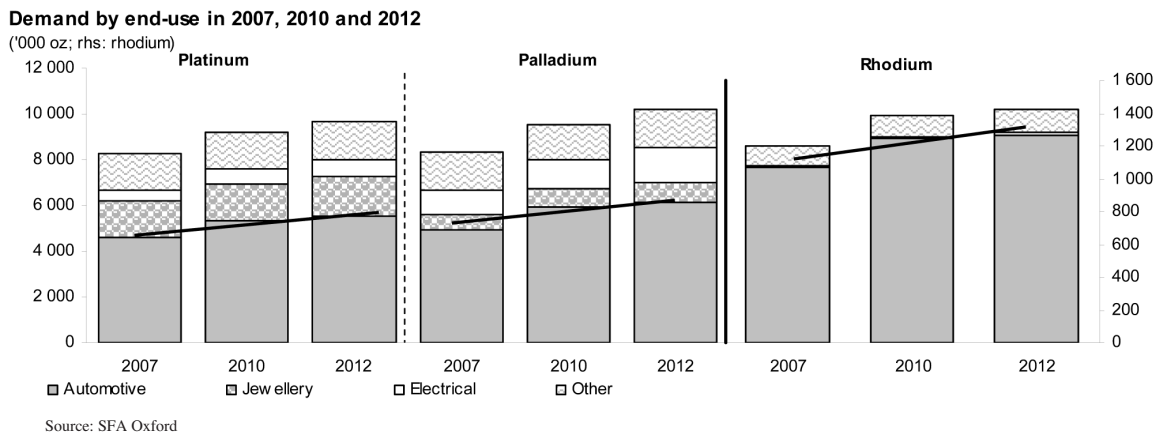


Figure 4. Extrapolation of platinum, palladium and rhodium end-use demand

increasingly stringent to reduce sulphur levels in diesel fuel to around 15 ppm in the USA, Europe and Japan from previous levels of around 500 ppm, at which palladium would be poisoned and rendered unusable. The substitution of palladium for platinum equates to an additional 50 koz by 2012 (see Figure 5) based on current and future diesel vehicle market shares.

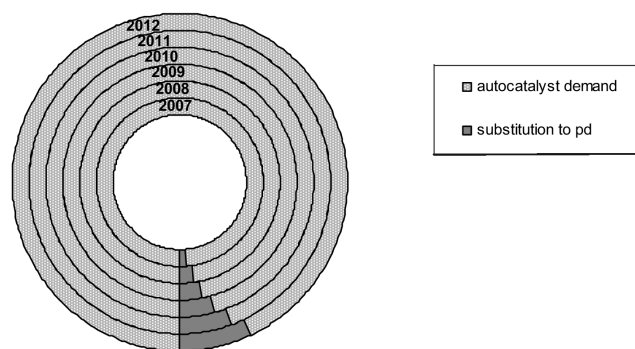
The automotive market is currently driven by the global need to reduce CO₂ emissions and the rising cost of fuel to consumers. Vehicle manufacturers are thus working to improve the fuel efficiency of all vehicles, particularly cars. In the USA, Congress recently mandated a 40% improvement in fuel economy by 2020 and the EU has drafted a proposal to cut CO₂ emission levels from cars by about 25% by 2012. These improvements in environmental legislative compliance and running costs are expected to sustain the demand for personal transport and for the use of PGMs in autocatalysts in these vehicles.

Last year was a particularly poor year for industrialized economy passenger car production, with year-on-year output falling in the USA by -7%, Japan by -6% and Western Europe levels remaining flat. Many industrialized economies should thereafter increase annual vehicle output, but only to 2010 when the shift east becomes more evident and a number of mature economies show declining car production levels.

From 2009 emerging economies become the largest vehicle producers. The prevalence of cheaper labour, an increasingly skilled workforce, new local vehicle brands as well as increasing wealth per capita are leading to a shift in vehicle production to Korea, China, India and Eastern Europe. Passenger car production growth in China is forecast to average 11% p.a. from 2007 to 2016, and including India (9% p.a.) and the rest of the world (4% p.a.), an overall 6% p.a. output growth rate is estimated for the emerging economies.

Most of the major automotive manufacturers are investing in a range of alternative propulsion technologies for cleaner cars, as no single technology yet appears to be superior to any other. Additionally, the diversity of consumers and driving environments makes it likely that a number of different technologies will coexist as manufacturers differentiate their products for the market.

The use of diesel fuel and hybrid engines and generally improved engine efficiency are the main approaches to vehicle CO₂ reduction. There are strong regional and manufacturer preferences. Fuel-efficient engines such as diesel or lean-burn gasoline engines make high demands on particulate emissions reduction, especially in NO_x reduction technology.



Source: SFA Oxford

Figure 5. Additional demand from the increased ratio of palladium in diesel automotive catalysts

Tightening automotive emissions legislation ensures strong demand growth going forward. Reductions in PGM catalyst loadings through nanotechnology, announced regularly by vehicle manufacturers, could ease pressures on rising end-use requirements. Nonetheless, with global demand-pull now coming from the East and China, PGM consumption is still set to show strong annual growth. The mounting environmental pressures to reduce vehicle emissions globally and the roll-out and wider adoption of increasingly stringent tailpipe emissions legislation will still lead to average annual growth in autocatalytic demand for platinum of 6.0%, palladium of 5.0% and rhodium of 6.0% out to 2010.

The importance of PGMs in autocatalysis and future threats

Platinum's particular chemical properties enable it to excel at the catalysis of CO and HC. In an autocatalyst, harmful gases are converted to harmless products in a reaction with the precious metal-containing catalyst. An autocatalyst is a cylinder of ceramic such as cordierite (or sometimes metal) with good thermal stability, formed into a very fine honeycomb coated with a layer of PGMs. The metal is in the form of nanoparticles dispersed over the entire surface of a highly porous support material, such as gamma alumina, applied as a washcoat over the support. This structure is mounted inside a stainless steel canister, creating a catalytic converter, which is fitted in the exhaust line of the vehicle between the engine and the silencer, either near to the engine (close-coupled) or further down the tailpipe (underfloor). Platinum is particularly effective at catalyzing the oxidation of CO and HC under oxygen-rich conditions, so has traditionally been the metal of choice for diesel engines.

Platinum and palladium are equally effective under gasoline engine combustion conditions. In a gasoline engine there is a balance between oxidants and reductants in the exhaust gas, so platinum and palladium are generally used in combination, the relative proportions depending on the relative costs of the two metals. Rhodium is generally also used in gasoline engines, specifically to catalyse the reduction of NO_x to nitrogen. Despite their high cost, platinum and palladium face no foreseeable competition in this area. Several other metals are good oxidation catalysts in other environments but do not have the thermal durability and resistance to poisoning necessary to survive in the harsh autocatalytic conditions.

Platinum has sufficient high temperature stability to avoid coalescing in exhaust chambers. As the temperature of the catalyst rises, the very fine metal particles become mobile and can coalesce (sinter), greatly reducing the surface area available for reaction. For many possible candidate catalyst metals, such as gold and silver, this occurs at temperatures below the exhaust-gas temperature for a typical gasoline car, precluding their use in three-way catalysts. Platinum shows no reduction in surface area under normal automotive operating temperatures.

Platinum is not easily poisoned by the presence of sulphur molecules, unlike copper and silver. Sulphur-containing molecules are present in all exhaust gas and metals such as silver and copper will react readily to form compounds, making progressively less metal available to catalyse the desired reactions. Platinum avoids this poisoning because it does not form compounds with the sulphur-containing species, so is only inhibited rather than irreversibly poisoned. A good catalyst must be able to

chemisorb the reactant molecules sufficiently strongly and in the right form to cover the entire surface so that they react with each other to form only the desired product. In order to be an effective catalyst, a metal must exhibit certain properties:

- High activity: the rate at which it makes the reaction occur
- High selectivity: the extent to which it produces the desired product rather than any others
- Long lifetime: how long it can be used before it becomes deactivated by poisons or loses its mechanical stability
- Platinum is particularly suitable where the selectivity is less important, such as in the catalytic combustion of hydrocarbons.

Substitution by base metals is always mooted, especially at times of high PGM prices, but no serious threats exist.

Most recently, gold and silver have been the focus of PGM substitution in autocatalysis.

Substitution by gold is actively being researched, with significant claims for its effectiveness. Currently, Nanostellar has some patents pending and the backing of the World Gold Council for its research but this technology is still very much at the development stage. Nanostellar has announced an autocatalyst containing gold, but still used in combination with platinum and palladium. Historically, gold has not demonstrated the high temperature stability against sintering to remain effective under automotive operating conditions, and it remains uncertain whether gold can survive the >100 000 mile test run for mainstream vehicle use.

Mitsui Mining & Smelting Co (MMSC) has announced silver-based autocatalyst technology for use in diesel particulate filters (DPF) from 2012 in industrial and agricultural applications. This development uses silver in conjunction with metal composite oxide, instead of platinum, to burn off soot formed in the diesel combustion process. MMSC intends to roll out this technology to trucks, buses and passenger cars, and the catalyst is now undergoing performance evaluation tests. Silver has well-

known weaknesses for automotive applications as it readily sinters and may vaporize at modest engine temperatures, and is susceptible to poisoning. According to MMSC, creating a complex oxide using silver and other metals (likely higher temperature catalytically active base or precious metals), the oxygen present can be used to burn off the particulate matter at low temperatures without the use of NO₂. Initial tests have shown durability up to 800°C, comfortably above the normal operating temperatures of around 400°C, and comparable soot combustion compared to platinum-based catalysts. It thus appears that this technology could be used for burning the soot on a DPF. However, silver is a poor catalyst for oxidizing NO to NO₂ which is vital for regenerating the filter when the vehicle operating temperature is low, as in city driving. Silver is also a poor catalyst for oxidation of HC and CO, so cannot replace platinum and palladium in the diesel oxidation catalyst (DOC). A further platinum DOC would be required to oxidize any residual HC and CO, which came through a silver-based DPF. The use of silver in a DPF is still most likely to be coupled with a PGM catalyst and any PGM replaced by silver in a DPF would, to some extent, need to be added back into the system elsewhere. It is unlikely that silver will replace any of the platinum and palladium used in a DOC or in gasoline three-way catalysts.

Jewellery

Strong Chinese demand and continuing marketing initiatives sustain platinum jewellery consumption.

The sharp rise in platinum turnover on the Shanghai Gold Exchange is a firm indication, along with elevated Chinese imports, that jewellery demand in this region continues unabated. Consumers in this region remain price inelastic.

Jewellery remains the shock absorber of the market as high platinum prices negatively affect demand (rising platinum prices resulted in a drop in consumption across all regions). Historically high prices are expected to take significant amounts of metal out of the platinum jewellery market each year from 2008 to 2012.

Platinum jewellery demand elasticity
(000's oz lhs; \$/oz rhs)

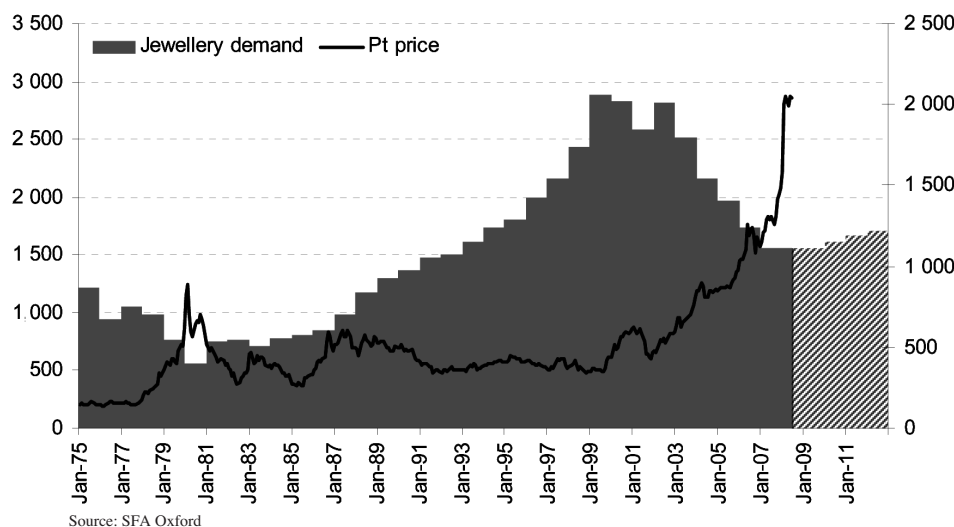


Figure 6. Platinum jewellery demand and price movements over time

Jewellery represents the market in which substitution is easiest. In the growing market for white metal, white gold is well established and will readily take market share from platinum and palladium as their prices rise.

Globally, a 10% increase in the platinum price could result in a 7% decrease in jewellery demand for the metal, while 10% income growth could result in a 27% surge in demand for platinum jewellery.

Jewellery remains the second largest market for platinum in each region. Demand for platinum in jewellery is forecast to grow, though with a slight decline in the share of total platinum consumption of 1%, from 19% to 18%. That growth in the platinum jewellery market is concentrated outside the USA, Europe and Japan. The greatest rise is expected in China, driven by the high levels of jewellery ownership in Hong Kong spreading to the mainland. Retailers have by no means given up on the more mature markets and, especially in the USA, significant consumer and trade marketing campaigns are underway.

Similarly, a 10% increase in the palladium price could result in a 6% decrease in jewellery usage, while a 10% rise in income could result in 9% growth in demand for palladium jewellery.

By 2012, jewellery demand for palladium will be the third largest market after autocatalysts and electrical/electronic uses. Consumption of palladium for jewellery is forecast to grow by 24% between 2008 and 2012, retaining around 9% share of the total palladium market.

Growth in the palladium jewellery market is concentrated outside the USA, Europe and Japan. The greatest rise is expected in China as with platinum, but as an emerging metal for jewellery use there are opportunities grow the market in other regions with a strong marketing campaign funded and currently being formulated by mining companies.

Conclusions

Demand for platinum, palladium and rhodium is forecast to remain strong and dominated by the autocatalysis and jewellery markets.

The autocatalysis market is driven by legislative requirements to improve fuel efficiency and reduce emissions of noxious materials, thereby boosting demand for PGMs. The growth of the Chinese and Indian car markets and their gradual adoption of tighter emissions standards more than outweigh any slowdown in the more mature European and US markets. Newer automotive technologies, such as clean diesel, gasoline and diesel hybrids and more efficient gasoline engines are likely to be neutral or positive for PGM demand, as emissions standards become ever more stringent. Some price-driven intra-PGM substitution is expected, as research efforts and improvements in fuel quality enable the wider use of more cost-effective palladium in the diesel market. Substitution announcements involving other precious and base metals continue, but none appear to pose a serious threat to the PGMs under the complex and harsh operating conditions of a vehicle engine.

Chinese demand for platinum jewellery is forecast to remain strong, and extensive marketing efforts continue to enlarge the market in most other regions. Jewellery is the shock absorber of the market, with historically high prices expected to take significant amounts of metal out of this market. Substitution for other metals is relatively easy in the jewellery market and white gold will readily take market share from platinum and palladium as their prices rise.

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Jenny specializes in PGM demand at SFA with particular emphasis on new technologies that may impact demand for PGMs. This includes monitoring and evaluating announcements that may offer new markets for PGMs and those that pose threats from thrifting and substitution. Recent assignments have included studies of the automotive market and the potential of alternative transport technologies to displace current vehicle technology. Previously, she worked on new product development (with several patents granted), technology transfer and process improvement in the industrial materials industry in Europe and the US.