SFA Oxford

THE PLATINUM STANDARD

May 2017

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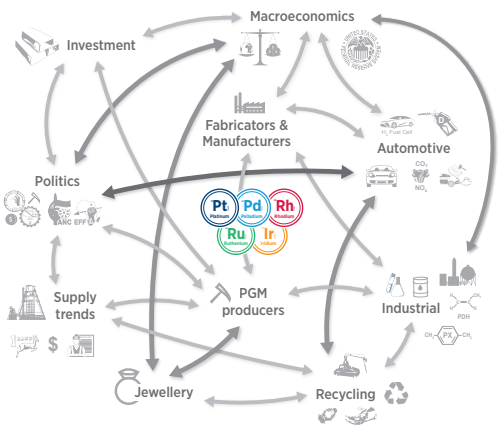
May 2017

Celebrating 15 years of PGM market analysis



Edition 06

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ONE TRILLION DOLLARS OF CLIENTELE

One trillion dollars of clientele

Stephen Forrest, Chairman, SFA (Oxford) Ltd

A world authority on PGMs

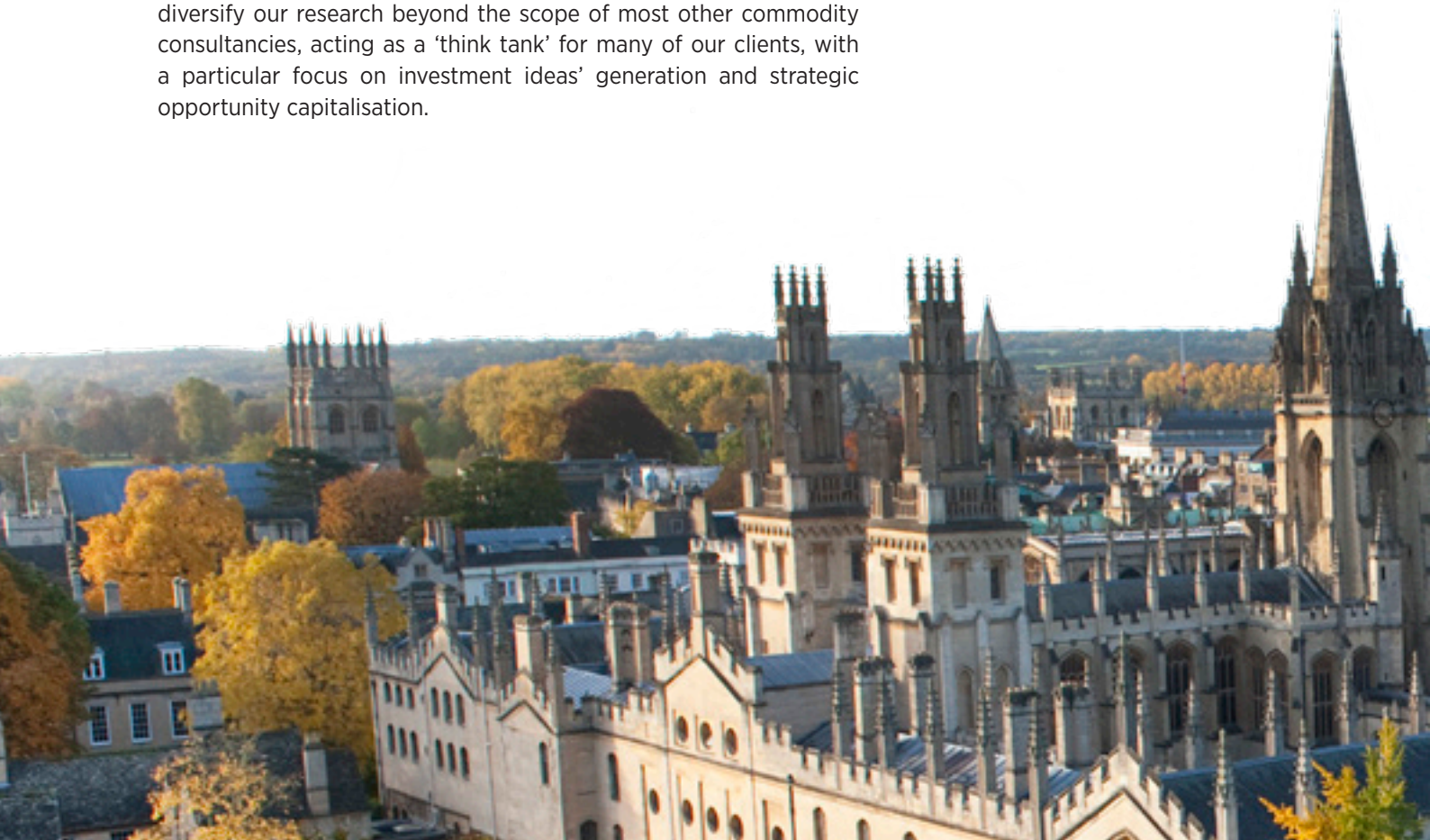
SFA (Oxford) has, for over 15 years, held a reputation as both a PGM authority and supply and demand specialist. Its understanding of the dynamics of the PGM industry is unrivalled, having fostered relationships with its most significant players across the globe, working alongside each one in partnership to enrich its individual business case, independently and in complete confidence.

Since starting out as a niche business in the early 2000s, SFA has evolved to become one of the world's leading commodity consultancies, mapping and working with the entire industry value chain – supply and demand – for many of the strategic metals, not least PGMs.

In the ensuing years, we have kept watch over the PGM industry, learning its innumerable intricacies and growing alongside it, with each one of our nine dedicated consulting analysts specialising in a particular supply and demand area, ranging from end-use authorities to supply specialists to value chain experts.

'Think tank'

The individual and collective expertise of our team allows us to diversify our research beyond the scope of most other commodity consultancies, acting as a 'think tank' for many of our clients, with a particular focus on investment ideas' generation and strategic opportunity capitalisation.

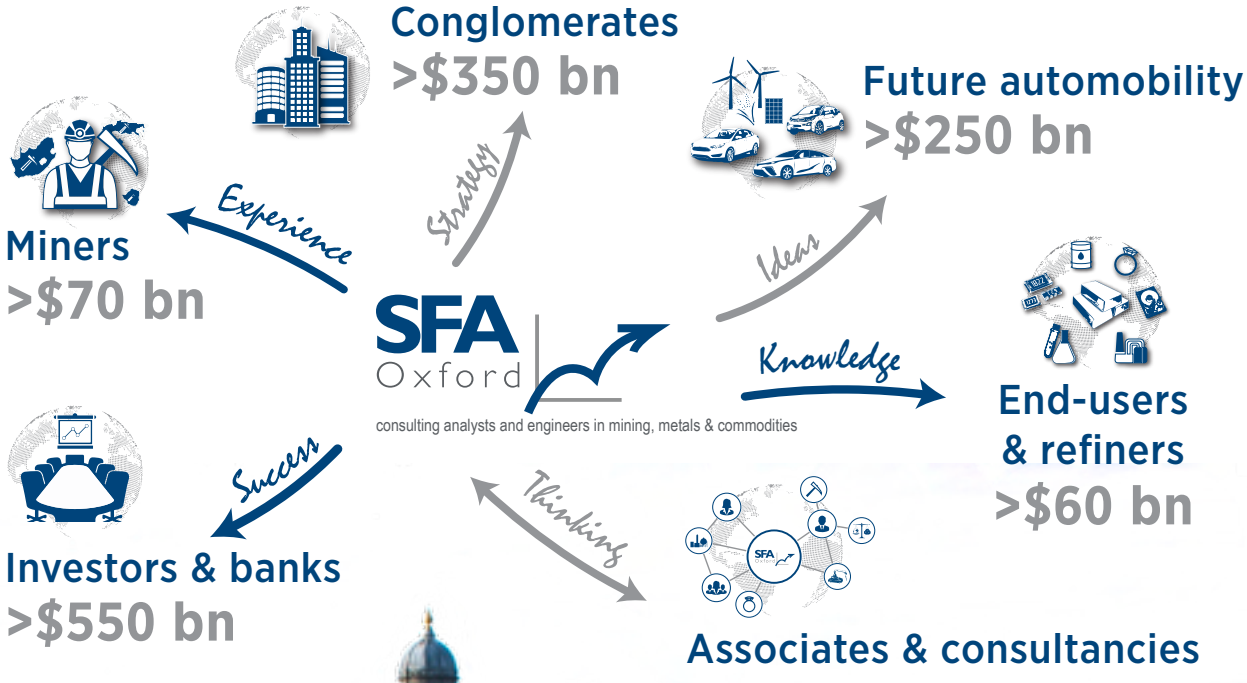


Intimate relationships and unique skills

Our unique network of clients and associates is the catalyst through which SFA has become the analytical link in the strategic metal value chain. This network extends across the world, encompassing all of the major producing and consuming regions, each one examined, understood and broken down, their intricacies and complexities articulated simply and coherently.

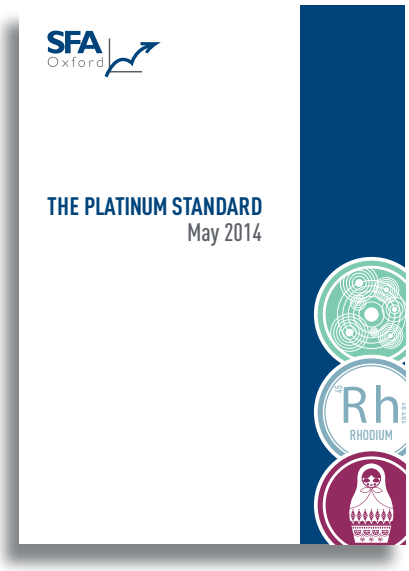
For many years we have also been trusted advisors to the commodity industry's major metal producers, with relationships built upon our analysts' delivery of granular, ground-breaking analysis.

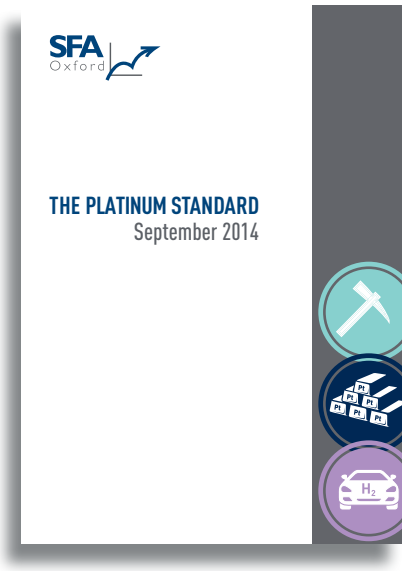
After 15 years, we are proud to have achieved a reach of over one trillion dollars of clientele*, delivering a greater comprehension of tomorrow.



* Market capitalisation.

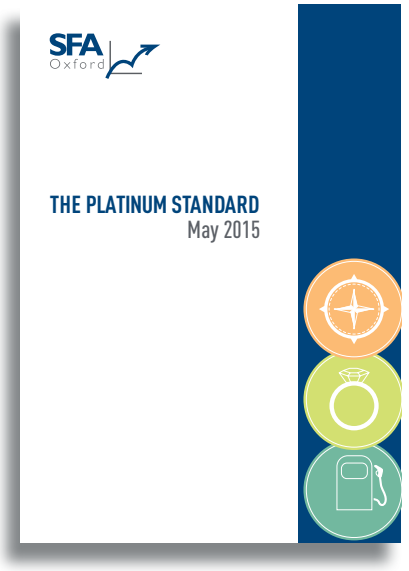
TPS COLLECTION: AGENDA-SETTING COMMENTARY

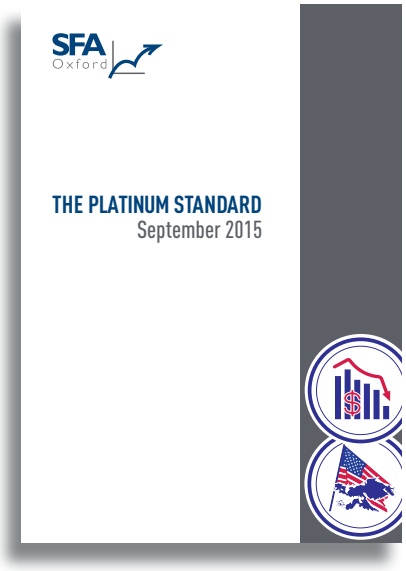




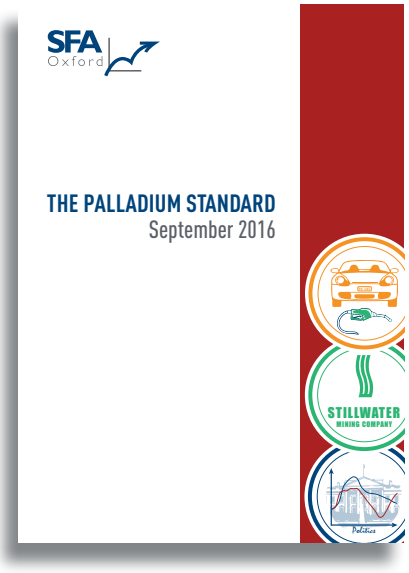
The Platinum Standard was launched in May 2014

One-half review, one-half preview, The Platinum Standard comprises analytical commentary on those issues we believe will set the PGM agenda for the years ahead





If you are interested in reading the collection, please contact our Head of Marketing, David Mobbs (dmobbs@sfa-oxford.com)



FOREWORD

Foreword

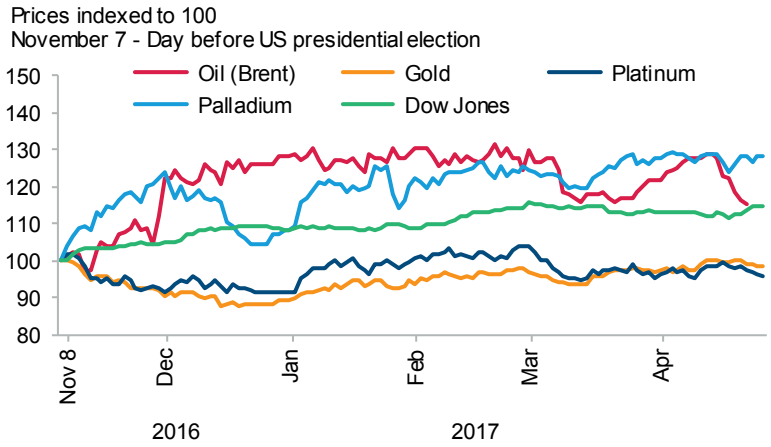
Something's up...

"Our experiences are improved, enriched and made joyful by being considered outside their obvious and intended context, by being viewed tangentially with a louche gleg – that's to say, an oblique squint."

Jonathan Meades, *Museum Without Walls*, 2012

...but not platinum. On either a 100-day...

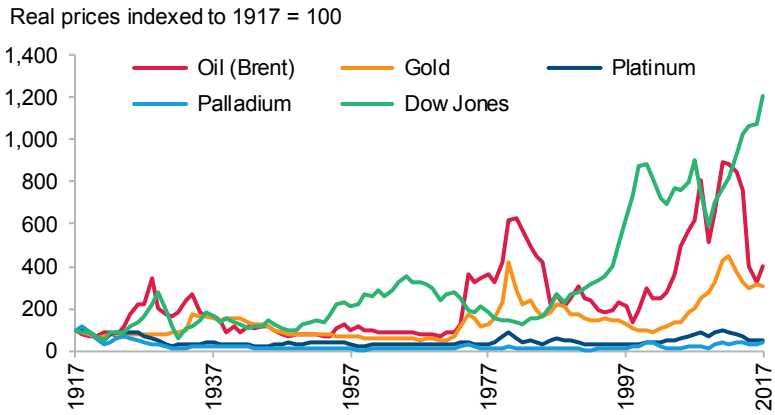
100 days later



Source: SFA (Oxford), Bloomberg

...or even a 100-year basis.

100 years later

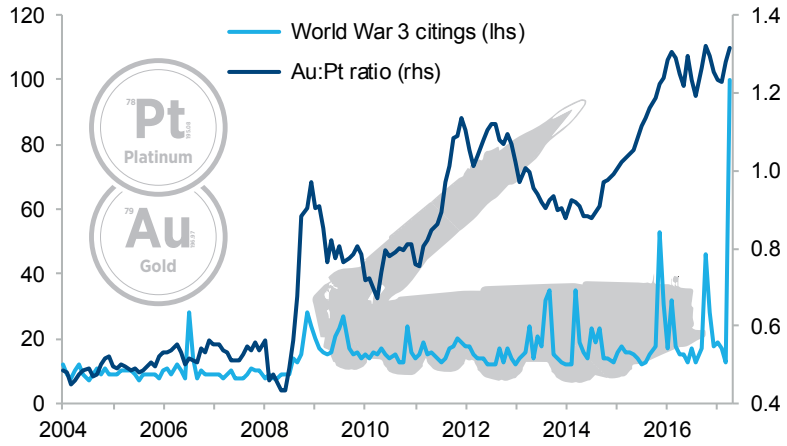


Source: SFA (Oxford), Bloomberg

Maybe there's a safe space for platinum investors in-between? The World Platinum Investment Council is leading the exploration party (as Marcus Grubb told a record audience at this year's Oxford Platinum Lectures (OPL) – attendees up by a half since 2013).

They may have to hurry. For the balloon appears about to go up. A dystopia flagged years ago by the rise of (haven) gold to a considerable premium over (hope) platinum.

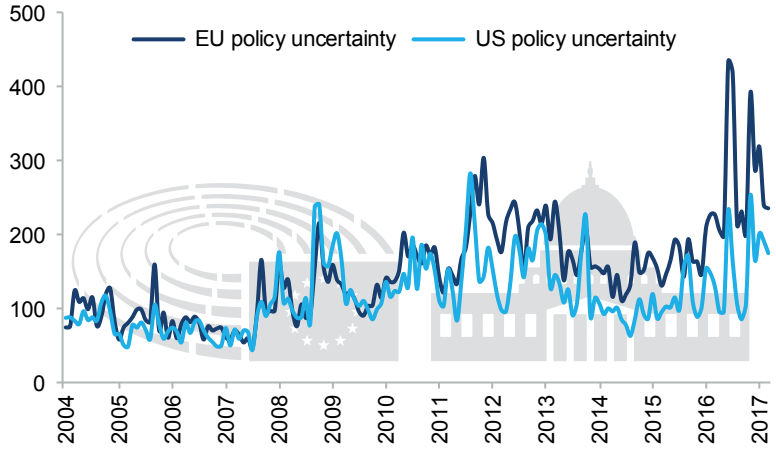
Boom?!



Source: SFA (Oxford), Google Trends

A dismal prospect signposted more recently by the uptrend in 'outsiders' in global affairs. Black swans seem to obscure the blue sky.

Policy (more) variable

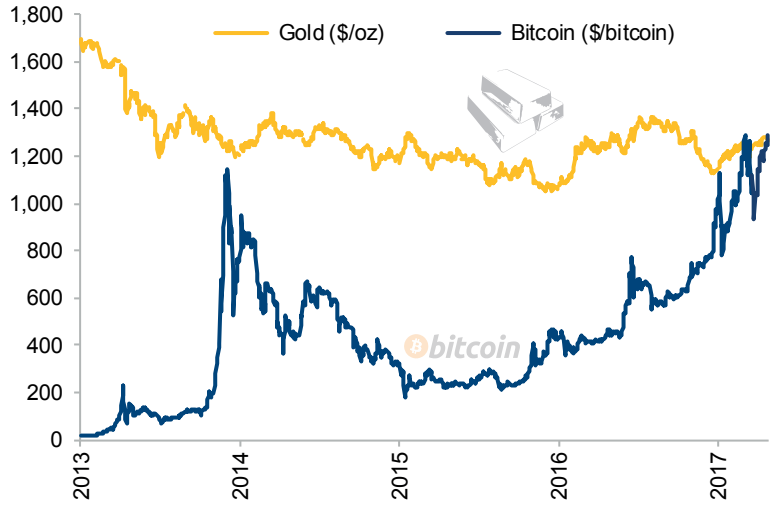


Source: SFA (Oxford), Policyuncertainty.com

A rustle of political feathers (the election of President Trump; Brexit) more familiar in South Africa (Paternoster traces the tortuous ways around the South African "abyss" in this issue of TPS) than in 'the North'.

'Total protonic reversal', then, as institutions crumble? A terminator state marked by the rise of the machine – including machine-made money usurping multi-Millennia-money gold?

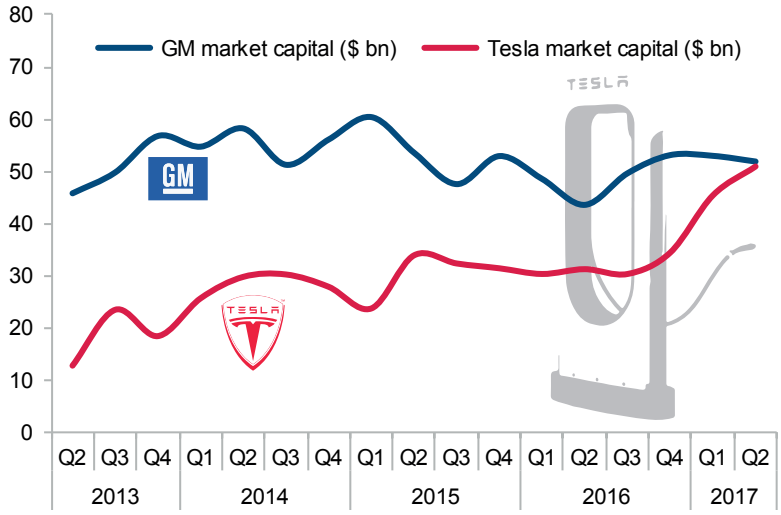
Don't cross the streams?



Source: SFA (Oxford), Bloomberg

And by a shocking upswing in electric vehicle pizzazz...

Electric shock



Source: SFA (Oxford), Bloomberg

...jolting the idea (if not, for a decade or more, the reality) of catalysts in internal combustion engines as a perpetual PGM demand machine. (Scott Brierley previously of GM electrified the OPL with parallels between the breakout of mobile phones and 'EVs'.)

Important safety tip

Dr. Egon Spengler:

There's something very important I forgot to tell you.

Dr. Peter Venkman:

What?

Dr. Egon Spengler:

Don't cross the streams.

Dr. Peter Venkman:

Why?

Dr. Egon Spengler:

It would be bad.

Dr. Peter Venkman:

I'm fuzzy on the whole good/bad thing. What do you mean, "bad"?

Dr. Egon Spengler:

Try to imagine all life as you know it stopping instantaneously and every molecule in your body exploding at the speed of light.

Dr. Raymond Stantz:

Total protonic reversal!

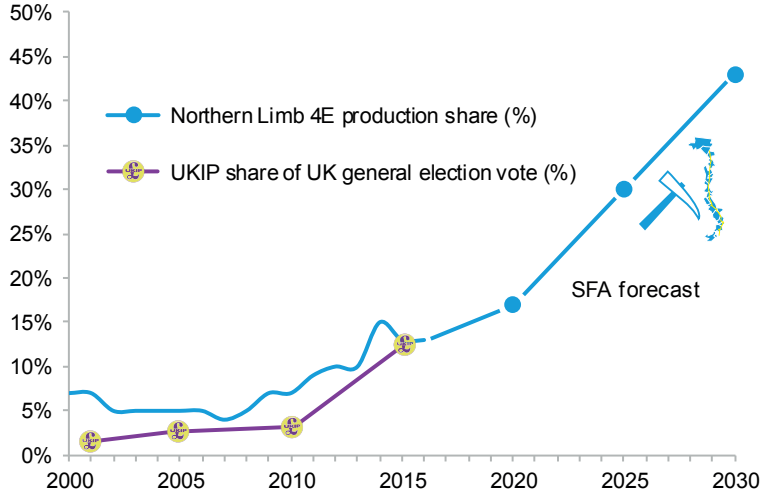
Dr. Peter Venkman:

Right. That's bad. Okay. All right. Important safety tip. Thanks, Egon.

'Ghostbusters', 1984

Indeed, as Sam Trickey explains in this TPS, machines (plus a wide, palladium-intense, polymetallic ore body almost tailored to future PGM demand trends) are powering up PGM output in the Northern Limb of the Bushveld Igneous Complex, South Africa. A phenomenon on the geological fringe to rival and almost certainly surpass that of the supposedly flakey UKIP ("fruitcakes, loonies and closet racists": David Cameron) in British politics.

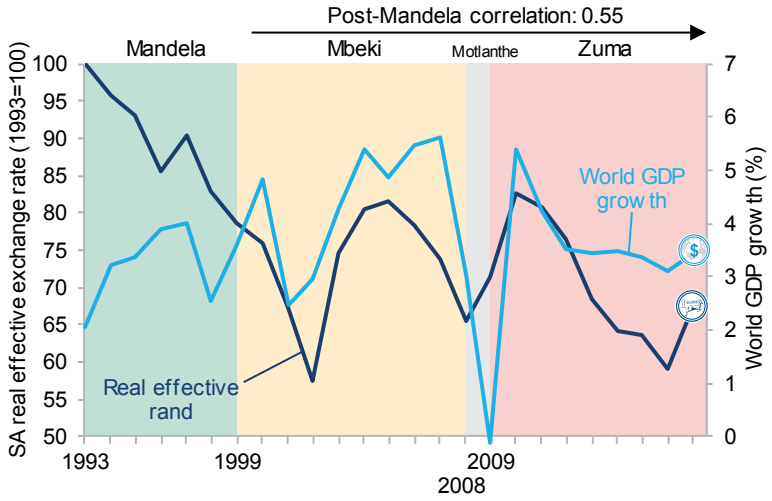
Out on a limb



Source: SFA (Oxford), Wikipedia

'The market' accounts for 39% of total risk to South African project development, according to Sam. And arguably this might be eased if there were the 'right' kind of political uncertainty – the kind that helped South Africa PGM Inc's competitiveness. After Messrs Mandela (-4% p.a. devaluation of the real rand) and Mbeki (-2% p.a.), Mr Zuma (-1% p.a.) has been a disappointment.

Devaluing South African leadership – required

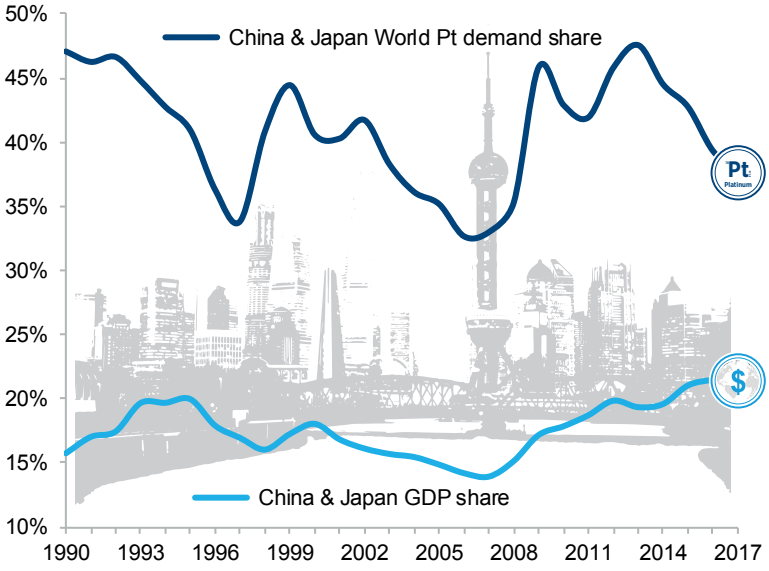


Source: SFA (Oxford), IMF

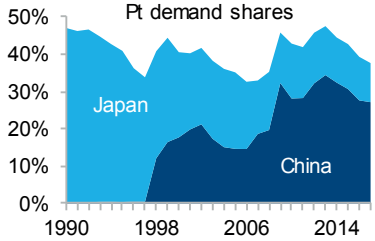
So is there anything left of the 'centre' of PGM to hold on to? In 1966, Ian Nairn, of whom Jonathan Meades was a big fan, introduced his *Nairn's London* with a desperate plea: "We must put out the fires and start healing this great place with the love and understanding it needs. It is already three parts gone; for God's sake let us leave the rest alone".

In platinum, let's start by bestowing 'listed building' status on 'the East', specifically Japan and China (whose investment and jewellery allure were polished by Jun Yamaguchi and Alan Chan at the OPL. Still wondering what Millennials are good for? Platinum jewellery demand, of course, Alan argued!). Their combined demand 'bang' is consistently twice their world GDP 'buck', and appropriate funds need to be devoted to its upkeep.

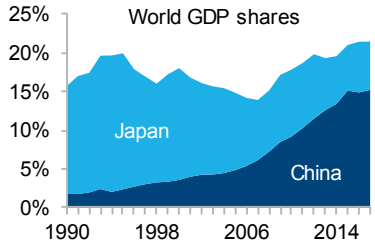
Platinum's cornerstone



Source: SFA (Oxford), IMF



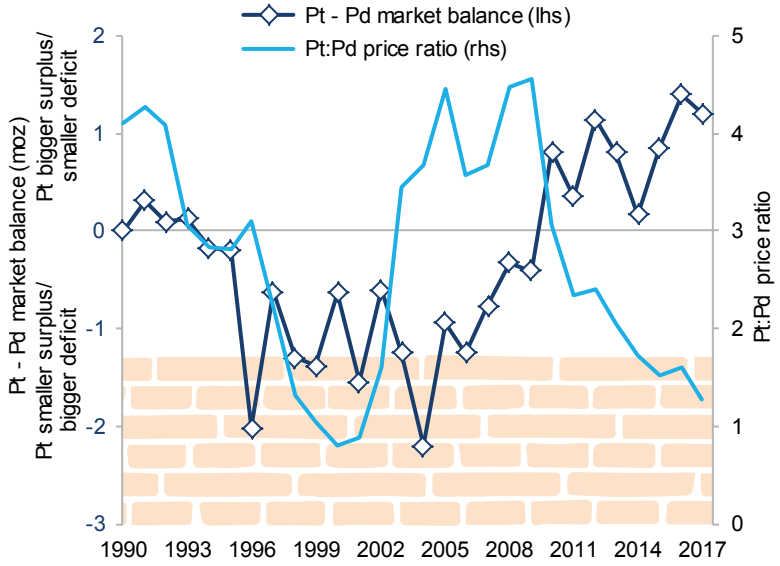
Source: SFA (Oxford)



Source: SFA (Oxford)

Next, let's acknowledge the writing on the wall (penned by Beresford Clarke in this TPS): palladium's demand/supply fundamentals now tower over those of platinum.

Palladium builds on solid fundamentals



Source: SFA (Oxford)

And, as Beresford explains, there are now 'new' bricks in the '5E' wall, namely iridium and ruthenium, currently on a price tear.

In summary, many of PGM's building blocks are up... in the air. As they are in politics, and, as Jonathan Meades reminds us, in life too: "We are persistently shocked when our children go straight from Lego to legover", aren't we?

Yours sincerely, The SFA (Oxford) team

SOUTH AFRICA'S COST BASE: OUT ON A (NORTHERN) LIMB

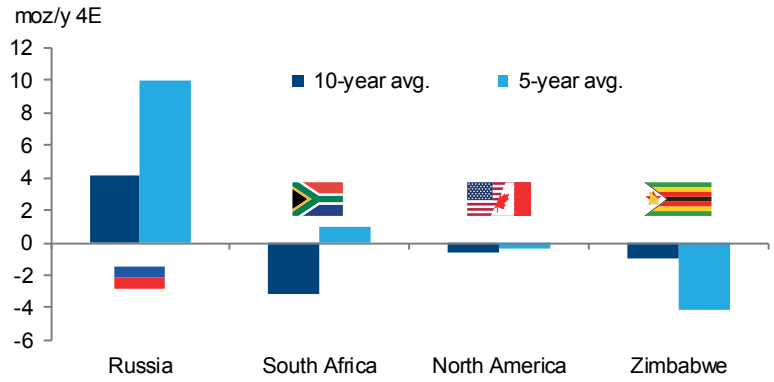
South Africa's cost base: Out on a (Northern) Limb

Samantha Trickey, Principal Supply Analyst, SFA (Oxford) Ltd

Restructuring constrains South African supply

Since the global financial crisis the platinum market has been in a state of near-constant industrial oversupply. Lower prices have prompted shaft closures, particularly affecting UG2 operations, and many South African producers have restructured and/or reduced production targets. Depletion rates for ore reserves in South Africa have slowed as a result. In fact, Zimbabwe and North America have overtaken South Africa for the highest reserve depletion rates over the past five years.

Reserve depletion rates



Source: SFA (Oxford)

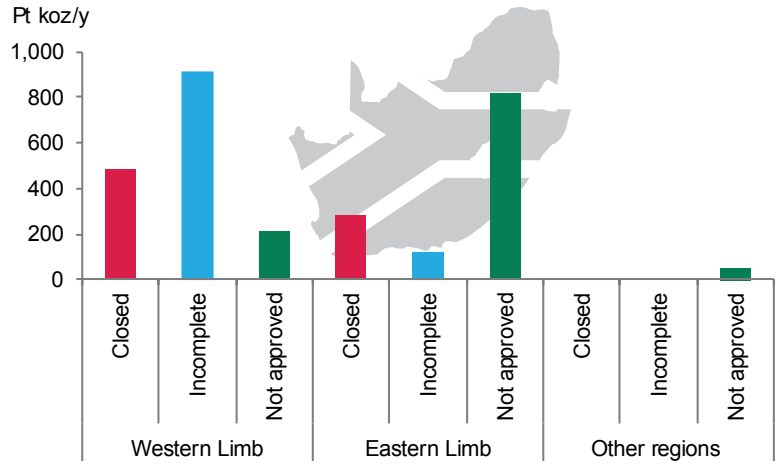
Lower and slower for South African supply

South Africa has averaged a reserve increase of 1.0 moz/y PGMs since 2012 – mainly attributable to the Northern Limb – versus a reduction of 3.1 moz/y over the previous 10 years. Shaft closures have taken place at a number of operations since 2008, exceeding 700 koz Pt, 400 koz Pd and 100 koz Rh in annual production capacity.

Significant capacity has been mothballed since 2008

Of greater significance in terms of volume are the brownfield and greenfield projects in South Africa that have been mothballed. Some 1 moz/y of unfinished platinum capacity is sitting idle on the Bushveld Complex (600 koz/y Pd and 160 koz/y Rh), and almost 1.1 moz/y in greenfield capacity (870 koz/y Pd, 125 koz/y Rh) was either not approved or stalled pre-construction following the global financial crisis. In combination with significantly reduced targets by existing producers, over 4 moz of planned platinum production failed to materialise in the late 2000s/early 2010s.

Mothballed capacity in South Africa

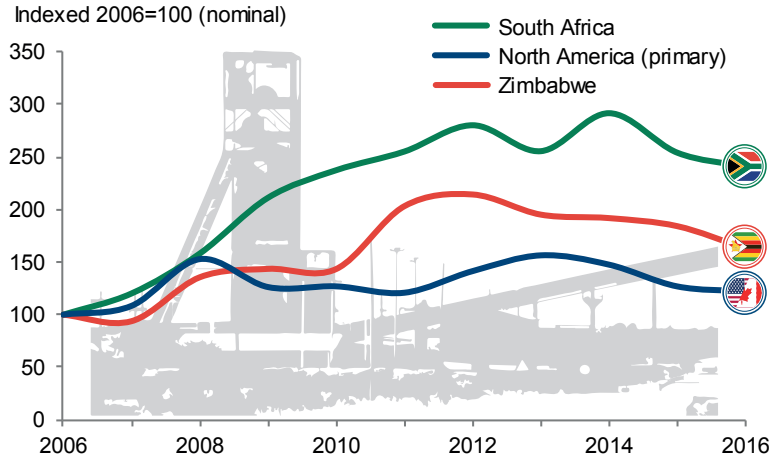


Source: SFA (Oxford)

Costs have improved, but not by enough

Despite this dramatic reshaping of the PGM supply landscape, the cost base has not improved relative to other PGM-producing regions. South Africa provides 70% of global platinum, 35% of palladium and 79% of rhodium production. Yet, it is the highest-cost producing region by some way – and that gap is not closing, notwithstanding the cost-saving measures undertaken since 2015.

Total cash costs per equivalent platinum ounce



Source: SFA (Oxford)

South African producers have cut costs, but so have other regions

Over the past two years, mining companies have worked hard to reduce expenses – cutting ZAR4.2 billion in OPEX and ZAR3.3 billion in CAPEX – and focus energies on their more profitable operations. This has, to some extent, increased competition *within* the South African PGM space and the cost curve for this region has become progressively flatter as a consequence.

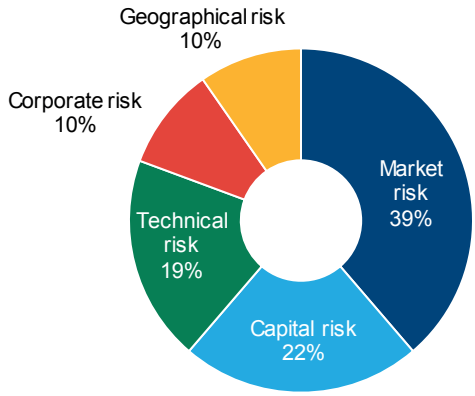
Overall though, the measures taken are a temporary fix to weather out a period of lower prices, and do little to ensure the sustainability and competitiveness of South African supply in the global context. In some cases, the reduced flexibility brought about by these changes is actually impairing the ability of producers to offset unplanned production losses (namely Section 54 stoppages, geological challenges and processing issues), which are driving up unit costs.

New PGM supply stymied by the markets

With many producers no longer in a position to grow their footprint – only a couple of companies are doing so today – we look now to the project peer group as a means of improving South Africa's competitiveness. Most of the economic value in PGM mining is centred on just a handful of deposits, albeit large ones, so it is important for project development to continue at all levels, from grassroots exploration through to feasibility work, in order to sift out those next generation Tier 1 assets.

Since 2008, 14 PGM projects (greenfield and brownfield) have been commissioned globally, but over 30 projects – which have reached at least pre-feasibility stage – have either stalled completely or been deferred. The key reasons for this are shown in the following chart. Market risk (lower prices, exchange rate volatility) has been the leading cause in the lack of project success. Of the project peer group, 39% have stalled because of market risk, including both single reef (UG2), and mixed reef/polymetallic projects.

Risk factors impeding PGM project development (2008-present)



Source: SFA (Oxford)

Market conditions dictate project development

Another important factor is capital risk. This affects projects for which spending has overrun capital budgets, or capital simply cannot be raised – either cash flow has not allowed it, or companies have been unable to tap a dried-up market. Some of these projects are particularly capital-intensive, including third-generation shafts and a large polymetallic deposit.

Inability to access sufficient capital has impacted 22% of the peer group, including projects located in South Africa (on the Western, Eastern and Northern Bushveld) and Canada.

Ranking behind capital risk is technical risk, which relates to ore reserve estimation (identifying uneconomic ore grades, essentially) and processing challenges. Technical risk factors have halted project progression for 19% of the peer group, mainly located outside of South Africa (Canada, Finland and Colombia) where ore grades tend to be lower.

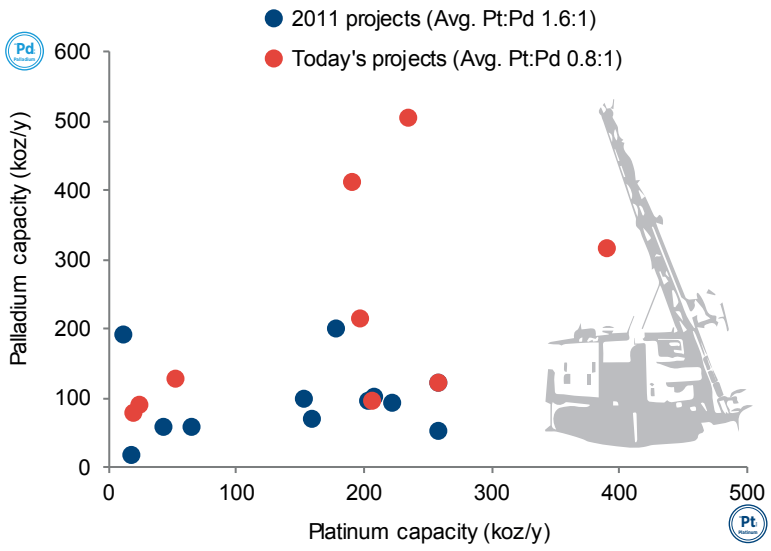
Corporate risk, in most cases, relates directly to market conditions. Going concern problems have hindered 10% of the peer group, for companies located in South Africa and North America. In Zimbabwe, a small number of projects (also 10% of the peer group) have been impacted by shareholder ownership issues and a lack of clarity in the legislative environment.

Some companies are persevering

A switch to more palladium-rich projects

As a consequence, there has been a significant shift in the composition of the project peer group in recent years with a move away from smaller-scale, predominantly platinum-rich projects to much larger-scale, wide reef, polymetallic (palladium-rich) deposits. This is shown in the following chart. The lack of the flexibility that small-scale projects offer means that, unless a deposit is particularly high quality, there is very limited scope for optimisation during a period of lower prices.

Project peer group capacities



Source: SFA (Oxford)

Flexibility (scale) is important for project success

Projects such as Booysendal are a good example of flexibility in the price cycle. This project was originally planned to comprise four decline shafts for a steady-state production total of 430 koz/y PGMs. The project was re-optimised during 2009 and split into two initial phases at 130 koz/y and 115 koz/y each. Booysendal North (at a reduced 160 koz/y) was completed in 2015. Booysendal South, sold to Aquarius Platinum in 2011 and re-acquired by Northam in 2015, will now produce 215 koz/y from 2022. This is a compelling argument for consolidation of the fragmented properties on the Eastern Limb, and an opportunity to improve South Africa's cost base.

Large-scale project development is taking place on the Northern Bushveld

In South Africa, Ivanplats and Platinum Group Metals (PTM) are progressing work on two large projects (Platreef Project, Waterberg) on the Northern Bushveld. A similar project is being developed in Zimbabwe (Darwendale). These projects are scaleable – that is, feasibility work has outlined ore production scenarios of up to 12 mt/y for the Platreef Project, 7 mt/y for Waterberg and 10 mt/y for Darwendale.

This means capital estimates range from US$0.4 billion (initial stage) up to US$1.8 billion for mining and concentrating infrastructure, and up to US$4.8 billion including smelting and refining capacity. Although pre-production costs are comparatively high, a diverse ore basket and potentially low operating costs mean these projects are more likely to succeed in a challenging operating environment.

These projects have also attracted the attention of foreign investors which are contributing to exploration activities, feasibility work and development costs. Japanese, Chinese and Russian firms have increasingly invested in African PGM assets since 2010. Completed transactions total US$1.35 billion in value (2017 money), while two further transactions failed to complete in 2014 and 2016 (together valued at US$282 million).

The Northern Bushveld has attracted foreign investment

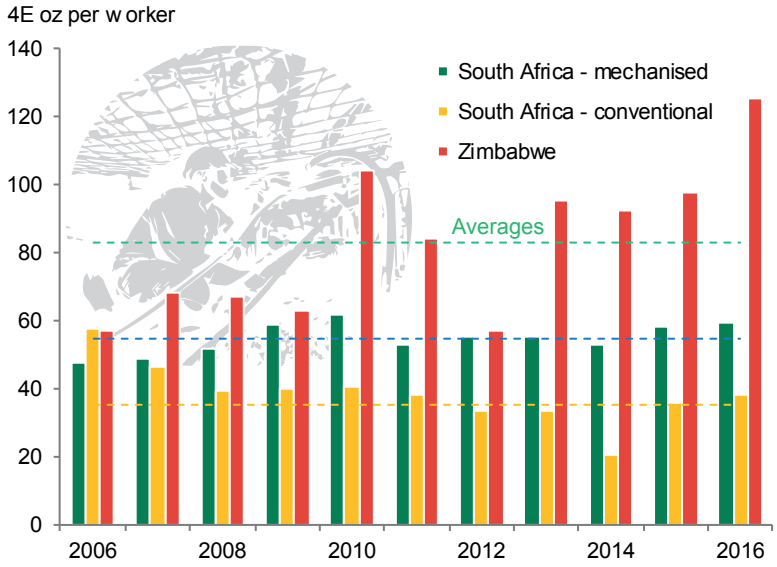
A Japanese consortium (comprising Itochu, JOGMEC and JGC) owns 10% of the Platreef Project, and has funded construction of 1 Shaft (US$300 million). JOGMEC is also currently contributing US$5.3 million towards completion of a feasibility study for the Waterberg project, in which it holds a 28% interest. In Zimbabwe, a Russian consortium (comprising Rostec State Corporation, Vi Holding and Vnesheconombank) has a joint venture agreement with the Zimbabwean government to contribute to the development costs of Darwendale.

Mechanisable ore bodies take precedence

Productivity is a key influence (risk) on the cost base for established PGM mines, particularly in South Africa. In conventional mines productivity has declined by 34% since 2006, whereas mechanised mines in South Africa have seen productivity improve by 24% over the same timeframe.

On average, mechanised operations are at least 50% more efficient than conventional operations, and the comparatively shallow reef in Zimbabwe (<500 mbs) means that the mechanised operations there are more than twice as efficient as South Africa's conventional operations, shown in the following chart.

Labour productivity

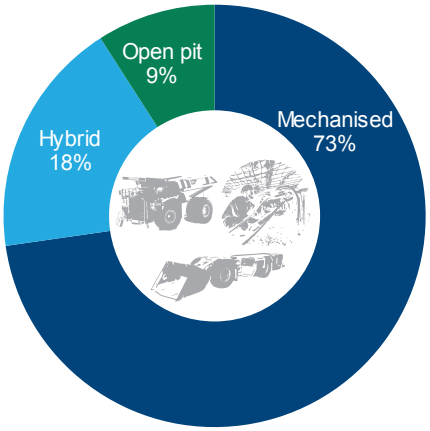


Source: SFA (Oxford)

The more advanced underground projects (at least at feasibility stage) in the global peer group are expected to be either part or fully mechanised; there are no fully conventional mining projects. Mechanisation, where the ore body allows, is not only more efficient and lower-cost than conventional mining techniques, but also reduces the reliance on people and is inherently safer.

Mechanised mining is more efficient and safer than conventional techniques

Proposed mining methods



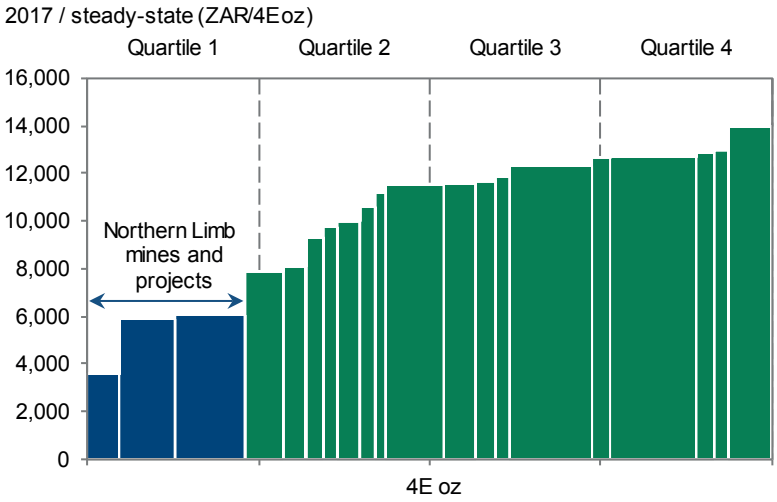
Source: SFA (Oxford)

A 40-50% Northern Limb contribution by 2030

The Northern Bushveld has become an area of focus in South Africa. Zimbabwe, despite its fundamentally attractive ore body, remains a relatively unexploited mining area owing to various political and economic constraints, but is slowly expanding. Projects in these areas are large scale with low operating costs.

Current published OPEX estimates for the Platreef and Waterberg projects are equivalent to a first quartile ranking on today's cost curve, shown in the chart below. With up to 2.3 moz of PGM capacity potentially becoming available within the next 15 years from these types of asset, we take a look at the implications for South Africa's cost competitiveness in a variety of scenarios.

Net cash costs



Source: SFA (Oxford)

A first quartile position is indicated for Northern Limb projects

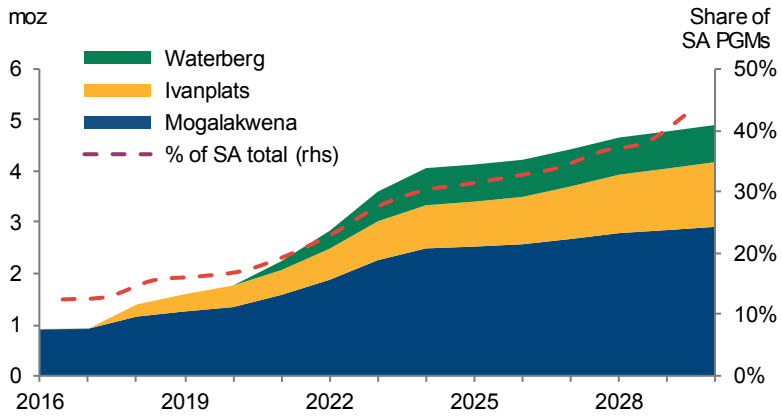
At full scale, Northern Bushveld projects could contribute over 30% of South African PGM supply within the next 15 years. Current plans see a 5% contribution from these projects by 2020, increasing to 20% by 2025. Including Mogalakwena – capped at current capacity, assuming no further investment in processing facilities to allow expansion – total Northern Limb production could account for 17% of South African supply by 2020, 30% by 2025 and 43% by 2030. Such growth will be dependent on market conditions, the ability of PTM and Ivanplats to fully fund the infrastructure, and available processing capacity (base metals, in particular).

At full stretch, with processing capacity in place, the Northern Limb could contribute almost 50% of South African supply

Best scenario is a ≤40% reduction in net TCCs

The base case supply profile includes a Northern Limb contribution from Mogalakwena of between 13% (2017) and 20% (2030, taking into account depletion at other operations). Increasing production from the Northern Limb to 30-40% of South African PGM supply by the mid-2020s could reduce the weighted average total cash cost (TCC) for South Africa by up to 11%, and the net total cash cost by up to 20% versus the base case. This assumes that Mogalakwena maintains current production levels (900 koz/y PGMs), Phase 2 (8 mt/y) of the Platreef Project is approved and the Waterberg project is commissioned and completed on schedule.

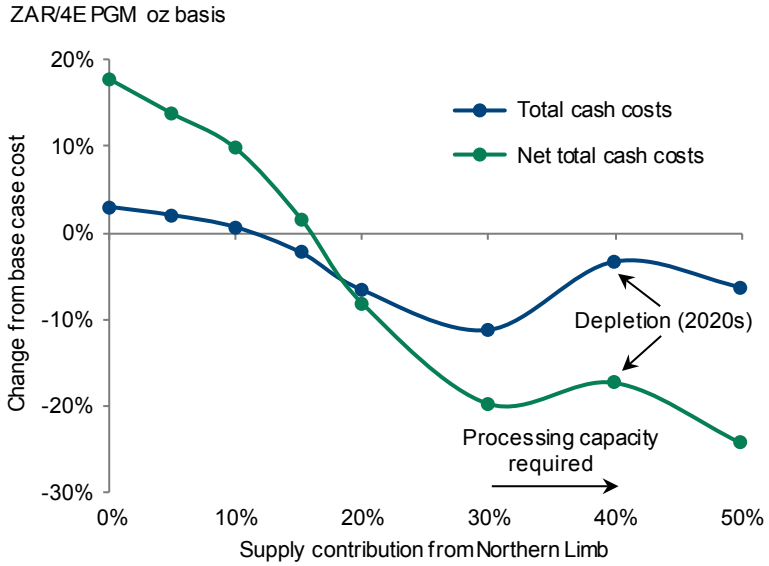
Northern Bushveld PGM production



Source: SFA (Oxford)

Above a 30-40% contribution, the cost benefit stabilises for two reasons. First, additional processing facilities are required to treat Northern Limb volumes around this point. Secondly, the impact of depletion on unit costs is factored in, given the time it will take for these projects to ramp up to ≥3 moz/y PGMs. Once critical mass is exceeded, Northern Limb supply contribution towards 50% may result in a significant reduction in net TCCs for South Africa (-24% versus the base case). Such volumes would entail all projects at full scale, plus expansion of Mogalakwena to 1.4 moz/y PGMs – a project that is currently shelved.

Weighted average unit costs for South Africa

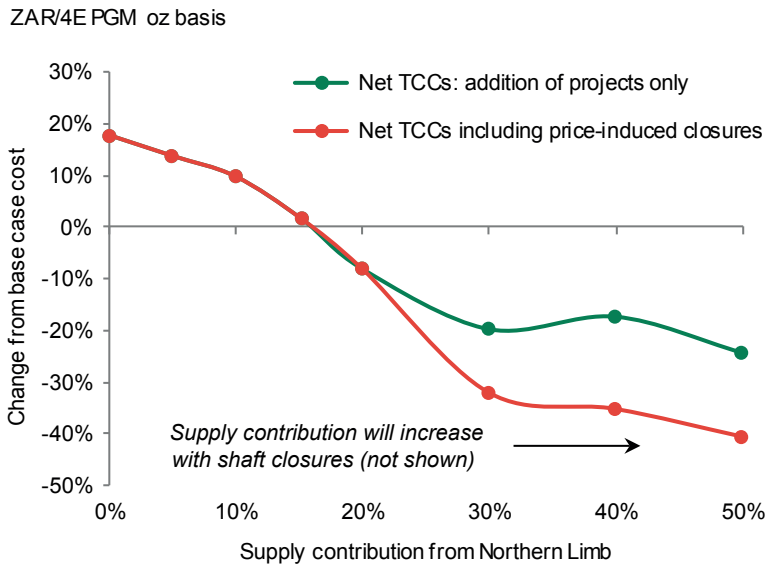


Source: SFA (Oxford)

Northern Limb projects could reduce the average net TCC by ≤24%

Northern Limb expansion may also displace operations positioned higher up on the cost curve. Here we assume an arbitrary threshold for price-induced closures is a 30% Northern Limb contribution, coinciding with higher depletion rates (rising unit costs in the fourth quartile) during the mid-2020s – but this may occur sooner or later, depending on market conditions. A total reduction of up to 40% in the average net TCC may be plausible on this basis, shown in the chart below. This lowering of South African costs may reduce the perceived floor price for platinum.

Weighted average net unit costs for South Africa
(incl. projects and price-induced closures)



Source: SFA (Oxford)

Fourth quartile shaft closures may reduce costs further

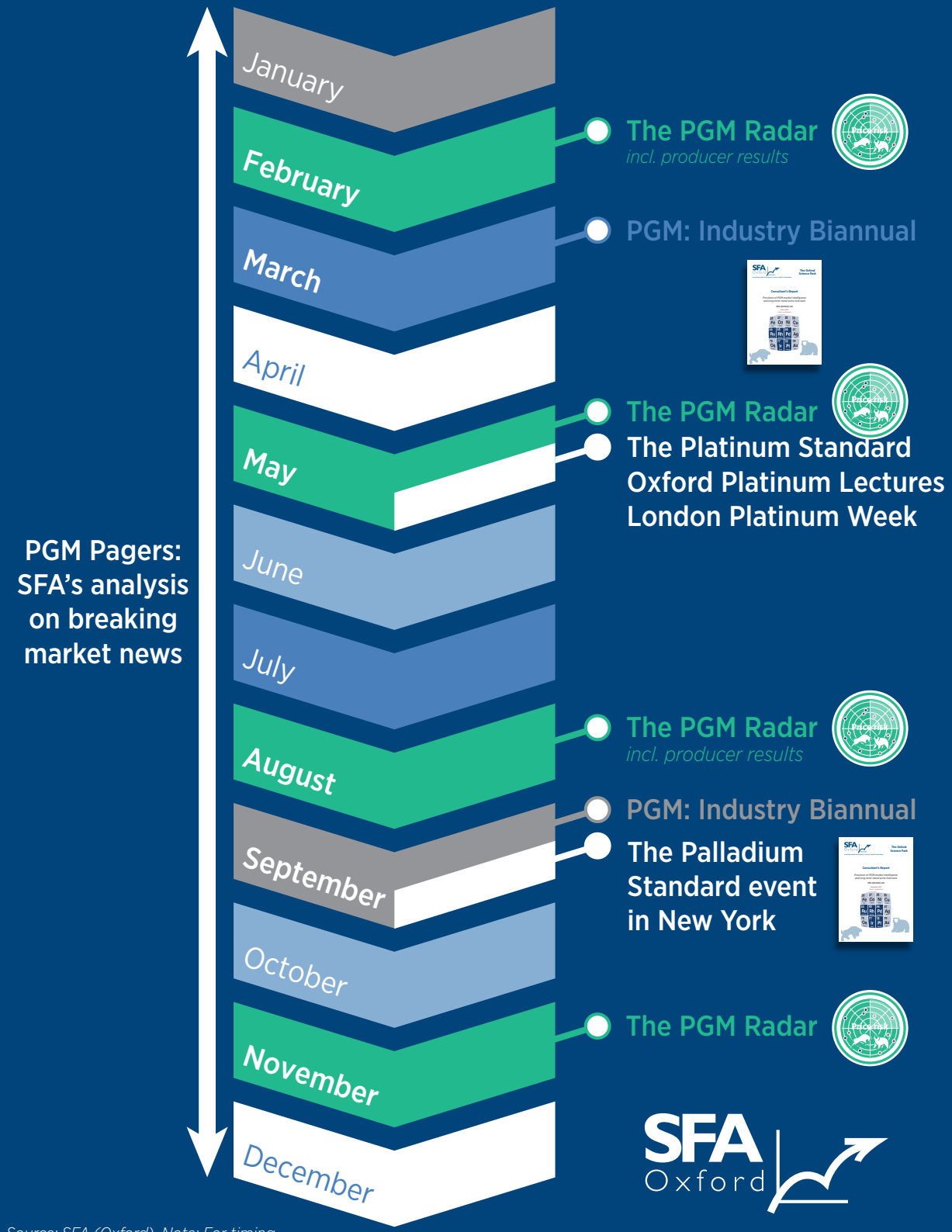
It must be noted that the long-term outlook for the South African currency has weakened significantly in the last six months. This could trigger higher inflationary pressures for existing operations, and may impact the development of projects sourcing equipment from overseas. A 'best case' scenario (≤40% reduction in net TCCs) assumes no such increase in inflation, and yields an average net TCC that is much more comparable to Zimbabwe, but is still unlikely to surpass it.

The platinum price averaged less than $1,000/oz in 2016 for the first time since 2005. Stay-in-business capital expenditure, as a percentage of operating costs, is the lowest it has ever been for South Africa and expansion capital reached a four-year low in 2016 (in both rand and dollar terms). This is not sustainable without a negative impact on producers' output, flexibility and productivity (costs), and does not allow the region to keep pace with the expansion and replacement projects now occurring in Russia, Zimbabwe and North America. On the Western Limb, most expansion opportunities are at depth (capital-intensive, high OPEX), but the Northern and Eastern Limbs are comparatively unexploited.

"It takes all the running you can do, to keep in the same place" – Lewis Carroll

The low rhodium price has largely stalled development of the Eastern Limb (a strong UG2 focus). However, on paper, the Northern Limb projects appear to have long-term strategic value for South Africa. They represent a significant opportunity to improve the country's PGM cost base, with the flexibility to scale production to market conditions – a key factor in the success of projects historically.

SFA'S PRINCIPAL PGM REPORTING TIMELINE

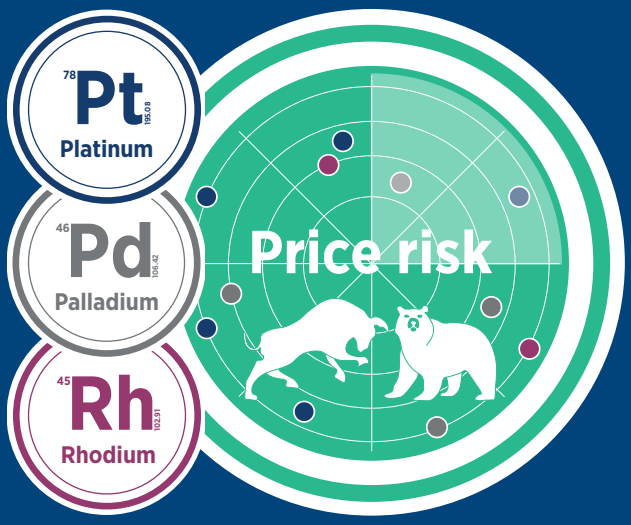


Source: SFA (Oxford). Note: For timing details on ruthenium, iridium and chrome market reports, please contact David Mobbs (dmobbs@sfa-oxford.com).

THE PGM RADAR

Short- to medium-term supply, demand and price forecasting

The PGM Radar, a risk-focused report that details on-the-horizon price-impacting factors, is the next evolution of our Quarterly Core Analysis Package (CAP), widely considered the benchmark in regular research of the platinum, palladium and rhodium markets. The report offers a brand new suite of analytical charts and scenarios, and is an essential guide to today's PGM picture.



Source: SFA (Oxford)

The CAPs are provided in concise bullet-point form to facilitate rapid understanding of the incorporated analysis and selected data. Specific content for each CAP varies according to market events and demand developments, but is tailored to incorporate the client's specific interests in the PGM industry. Typically, each CAP includes:

- Macroeconomic developments on supply and demand fundamentals and technology.
- Updates and advice on the present and future stability and growth of primary platinum supply and demand.
- Comment on the political and socio-economic risks impacting primary platinum supply in politically sensitive PGM-producing regions (e.g. South Africa, Zimbabwe and Russia).
- Short- and medium-term metal pricing outlook.
- Tracking and reporting relevant processes and technology developments in the market and likely impact on the sector.
- Future evolution and development of industrial technologies.
- Developments in demand/supply that impact on SFA's central case including the secondary and recycling sectors.

Each CAP report is supported by a conference call a few days after receipt of the document. Additional analysis and data arising from discussions may also be made available at that time.

For more information please contact David Mobbs (dmobbs@sfa-oxford.com).

PGM: THE INDUSTRY BIANNUAL

Long-term supply, demand and price forecasting

Strategic decision making

Board-level motivation

End-use evolution

Legislation drivers

Political risk

Recycling loops

Sustainability

Expansion windows

Food chain economics

Investment appraisal

Technology pathways

PGM: The Industry Biannual is a highly detailed report, produced around March and September each year, and typically of about 180-200 pages

Substitution threats

Demographic shifts

Competitor analysis

Capital raising

Scenario implications

Energy megatrends

Opportunities from innovation

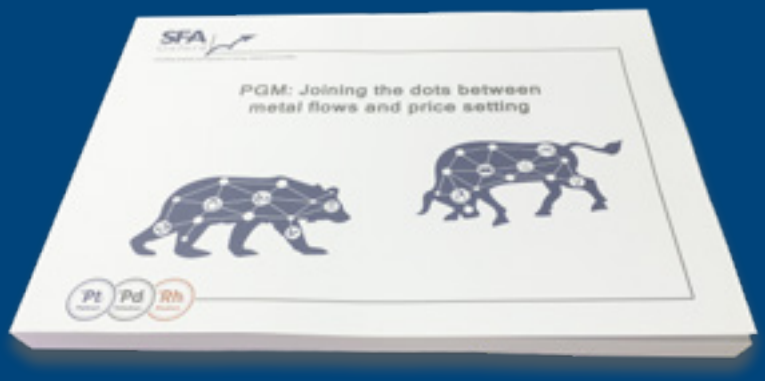
For more information please contact David Mobbs (dmobbs@sfa-oxford.com).

World Trade Center Complex, New York

PGM: JOINING THE DOTS BETWEEN METAL FLOWS AND PRICE SETTING

The real world of PGM pricing

PGM: Joining the dots between metal flows and price setting report provides answers to PGM commercial questions which we have all posed. Our report contains unrivalled insight, with over 300 pages of detailed analysis, commentary and charts providing unique exploration of the purchasing dynamics between market participants, the complexity of the associated price web and which factors drive metal prices for platinum, palladium and rhodium.



- Where is the price made and to what extent does this reflect the physical movement of metal?
- Who trades on the London 'Fix' (auction) and what is the volume of trade?
- How do the demand-side participants (automotive, jewellery, and industrial) source their metal, and how do they price it?
- How do the supply-side participants (producers and recyclers) sell their metal, and how do they price it?
- How are contracts on futures markets (NYMEX, TOCOM) priced, and to what extent does trade on these markets actually result in the physical movement of metal?
- What is the history of estimated above-ground stocks and how does this look against prices for each of the metals?
- Where do above-ground stocks sit (split by OEM, fabricator, jewellery, industrial, investor etc.), and when these stocks are being drawn down, where are these transactions taking place and how are these trades being priced?
- How can an analysis of the supply-demand balance over the last 10-20 years highlight the drivers of spot price changes for each PGM over time?
- What were the event-driven impacts on price and how did these detach the price from fundamentals? How did PGM prices react to these events compared with other commodities?
- What is the link between purchasing demand and end-use demand and its impact on price?

The report is supported by a conference call directly with the team of analysts, which follows a few days after receipt of the document. SFA is also available for a presentation to a client's Board or senior executives on the key findings, to ensure they are fully appraised of worldwide metal flows and price setting.

For more information please contact David Mobbs (dmobbs@sfa-oxford.com).

PGM: SPENT AUTOCATALYST RECYCLING MAPPED AND ANALYSED

SFA has, for more than a decade, comprehensively tracked the development of PGM usage and subsequent PGM scrap generation in the autocatalyst (as well as jewellery, electrical and electronic) sector. This was enhanced by an in-depth review in 2016 of the recycling business. SFA's detailed Core Analysis Package of the full recycling sector therefore provides a client with an independent review and up-to-date analysis of the autocatalyst recycling sector.

This substantial uplift in PGM recycling intelligence and know-how has been commissioned and verified by a number of secondary PGM recyclers. SFA has unique access to, and use of, the latest data, updated on a quarterly basis directly from a primary source.

The SFA team has developed a detailed Core Analysis Package report on the autocatalyst recycling sector that incorporates our understanding of:

- The competitive landscape: a complete overview of the autocatalyst business.
- Global autocatalyst recyclers mapped.
- A review of the business models of recyclers including SWOT evaluations.
- A complete assessment of each part of the value chain including technologies employed.
- An independent view on the economics of recycling: audited value chain presented.
- Scrap steel price impact on recycling volumes and grades.
- Ceramic substrate and PGM volumes: now and in the future.
- Major risks to the recycling business ahead.

The report provides unrivalled insight with over 400 pages of detailed analysis, commentary and charts, and is supported by a conference call directly with the team of analysts. SFA is also available for a presentation to a client's Board or senior executives on the key findings to ensure they are fully appraised on this study on the spent autocatalyst recycling industry.

For more information please contact David Mobbs (dmobbs@sfa-oxford.com).

Decanned spent autocatalyst ceramic

AN AGE OF UNCERTAINTY: SOUTH AFRICAN POLITICS ON THE EDGE

An age of uncertainty: South African politics on the edge

The Paternoster Group – African Political Insight Ltd

South Africa is at a crossroads. One road leads to a downward spiral of Zimbabwe- or Venezuela-like populism and nationalist chauvinism under the banner 'radical economic transformation'. A middle road means more or less more of the same, with South Africa stuck in a rut, unable to make the decisive structural reforms necessary to unlock its true economic potential. And a third – the high road – offers the promise of a new social compact, coupled with policy certainty and a clear-minded view of what the main economic and social actors must do to create jobs, drive inclusive growth and promote social cohesion. A pivotal question is whether the country can pull itself back from the abyss, as it has done many times before.

Can the country pull itself back from the abyss?

Current political context

South African President Jacob Zuma is in a corner, fighting vigorously for his political life. Having come to power as President of the ANC in 2007 on the back of popular support from various constituencies within the party, Zuma now finds himself increasingly isolated, relying on populist rhetoric to cultivate support for his survival. Since the watershed judgement of the Constitutional Court in March 2016 declaring that he had violated his constitutional responsibilities in relation to the renovations of his private residence at Nkandla, Zuma has been on the back foot. Calls for his removal from office have grown louder over the last year, evidenced most recently by large demonstrations and protests across South Africa. Civic activism has been reinvigorated, challenging the political hegemony of the ruling faction in the ANC from within and outside the party.

Zuma is at his most dangerous and unpredictable when he is under attack. The recent protests and renewed calls for Zuma to stand down followed his 'night of the long knives', when at close to midnight on 30 March he executed the biggest and most far-reaching Cabinet reshuffle since the end of the government of national unity in 1996. Out went the Minister and Deputy Minister of Finance, Pravin Gordhan and Mcebisi Jonas, and fierce Zuma critic, Derek Hanekom. The removal of the finance heads prompted downgrades to sub-investment status by S&P and Moody's. As a consequence, the country may be heading towards a Brazil-style tailspin that could set its economic prospects back by several years, or indeed see it head in a Zimbabwe- or Venezuela-like populist direction.

Election line-up?

Cyril Ramaphosa

Nkosazana Dlamini-Zuma

Supra Mahumapelo

David Mabuza

Ace Magashule

The next 24 months will set the course for the next generation

This has resulted in a climate of great political instability, which, when coupled with an economy veering towards a recession, has profound implications for the future of the country. Decisions taken in the next 24 months will set the course for the next generation of South Africa's democratic evolution, politically, economically and socially.

Never before has the ANC been so acutely and bitterly divided. This is reflected in the calls for Zuma to step down immediately from the succession battle, as well as the policy trajectory the ANC seeks to embrace. A vast array of forces is lining up to call for Zuma to leave office – he is seen as a liability to the party, as evidenced by the poor performance in the August 2016 local government elections. The ANC's Alliance partners, the trade union federation COSATU and the South African Communist Party (SACP), have made this call, supported by many within the 80-member National Executive Committee (NEC), the top leadership structure of the ANC. Zuma faced down an impromptu motion of no confidence at the NEC meeting in November 2016. His support within this highest decision-making body of the ANC between National Conferences is precarious. Assuming he survives an imminent vote of confidence in parliament, he may face a similar revolt at the next scheduled NEC meeting at the end of May 2017.

Battle for ANC leadership may decide presidency

Who will succeed Zuma? Jacob Zuma's term of office as President of the ANC comes to an end in December this year at the party's National Conference, held every five years. This will mark the end of 10 years of Zuma as President of the ANC. Whilst the ANC constitution contains no limitation clause for the number of terms an elected official can hold, the Constitution of the country limits a President to two terms of five years. The battle for succession to Zuma is therefore a key focus for the ANC this year, and it has become a proxy for control of government, with two rival camps engaged in a bitter contestation for power:

- Those who actively promote a lurch towards populist nationalism in policy outlook under the banner of 'radical economic transformation', and who largely support the candidacy of Nkosazana Dlamini-Zuma (the former Chairwoman of the African Union Commission, and former wife of the current President) to be the next President of the ANC. This group is widely considered to actively participate in, or at the very least condone, corruption and patronage. It is yet to be seen whether Dlamini-Zuma is capable of rising above this corrupt image and asserting good governance; and
- The 'constitutionalists' who seek to protect the integrity of key institutions of governance, including the National Treasury, and who wish to promote 'inclusive growth' by 'recalibrating' current fiscal and macroeconomic policy; they largely support the candidacy of Deputy President Cyril Ramaphosa who is standing on an anti-corruption ticket to succeed Zuma as leader of the ANC

Thus, South Africa faces its own populist nationalism threat, in the form of a call for 'radical economic transformation' that is now backed by President Zuma. A strong and increasingly vocal nationalist faction has emerged within the ruling ANC in recent years, sponsored by Zuma's own patronage network and backers, and provided with political shelter by the President himself. Institutional corruption has grown as this grouping has proceeded with its aggressive strategy of 'state capture'. It attacks what it disparagingly calls 'white monopoly capital'. Until his removal in late March, Gordhan and the National Treasury held the line, despite increasingly vituperative attacks. Now that he is gone, replaced by a compromised member of the nationalist faction (Malusi Gigaba), the Treasury is exposed and all bets are off. A supine Minister of Energy, Mmamoloko Kubayi, was also appointed to steer the controversial nuclear procurement deal. This has now been dealt a severe blow by the Western Cape High Court which ruled on 26 April 2017 that the purported agreement with the Russian agency Rosatom was unlawful and set it aside. Unless Zuma forges ahead, ignoring the courts and due process – a high-risk strategy – it is unlikely the deal can be concluded before the 2019 national election.

End of June ANC Policy Conference sets agenda for end of year National Conference and manifesto for 2019 national election

Policy-making could also be 'captured'. The ANC will hold a Policy Conference at the end of June in preparation for the National Conference at the end of the year. It is intended to review and debate policy positions, and prepare resolutions for the December meeting. Resolutions passed in December will, in turn, find voice in the ANC election manifesto in 2019. Careful attention will need to be paid to whether the nationalist faction mounts a strong assault on the moderate and sensible positions adopted in the draft policy documents that are under discussion now. The policy-making process currently remains in the hands of a relatively sensible group of people, such as Enoch Godongwana, who heads the ANC National Executive Committee's sub-committee on economic transformation, and who will try to hold the line in the face of a growing clamour for more populist policy positions. The new Finance Minister has sought to emphasise that economic policy has not changed and that inclusive growth is still the mantra, while at the same time appointing a pro-nationalist adviser in the form of Professor Chris Malikane.

Regardless of who prevails, the situation cannot continue as it is, as Pravin Gordhan emphasised in his Budget speech on 22 February 2017. The question is: what needs to change and how? Unfortunately, the rating agencies' downgrades will add further pressure on the economy and limit the government's options, as its cost of borrowing increases and further constrains the national fiscus. An economic recession is now very likely to follow.

Structural constraints are not being tackled!

Structural economic reform is urgently needed to respond to the socio-economic crisis. South Africa's population is projected to grow by up to six million by 2030, but the economy is simply not growing fast enough to absorb the extra socio-economic pressure that will accompany this rise. Currently, the economy's growth rate is just below 1% and unemployment is around 35%. Hence, there is growing recognition that South Africa's current socio-economic development trajectory is not sustainable: it is not creating enough new jobs and is not making much progress in reducing inequality. The government is failing to tackle the triple challenges of unemployment, inequality and poverty that it set as its priorities; not enough wealth has 'trickled down'. The structural constraints in the economy – such as poor education and low skills – are not being seriously addressed. In this context, a more urgent and decisive approach to economic management and to shifting ownership and control of wealth through inclusive growth is not only justified, but also an imperative.

Land reform and redistribution has emerged as an emotive and distracting issue – one that will not go away in the near future. Although he held back at the State of the Nation Address (SoNA), Zuma has spoken publicly about expropriation of land without compensation and with increasing vehemence as he seeks to maintain a grip on the rural poor and key provincial allies – an issue that is likely to bubble away for the foreseeable future. Given the socio-economic pressures, the militant stance of the Economic Freedom Fighters (EFF) party, and the growing populist tendencies within the nationalist camp of the ANC, this is likely to become more important and cannot be ignored as a lightning rod issue for 'transformation' that will frequently be used to beat 'white monopoly capital'.

Future political scenarios

It is not just a question of who wins the ANC's succession race, but how they win and by how much. A great deal depends on how the ANC's internal electoral process plays out. The ANC's electoral college is complicated and there is scope for gerrymandering. It is not yet apparent which of the two front-runners has the clearer route to power, in terms of the ANC's numbers game. The only candidate who can achieve the high road scenario is Cyril Ramaphosa. His main opponent, Nkosazana Dlamini-Zuma, offers at best only the middle road. If she wins on the back of the support of the so-called 'Premier League' members of Zuma's patronage network and is beholden to the NEC (which is elected at the same time as the President and other 'top six' positions of the ANC leadership), she may veer off towards the low road. If she falters, or drops out, and a full-on nationalist (such as one of the 'Premier League' provincial premiers) takes her place and wins, then the ANC will split, leading to greater instability ahead of the 2019 national election and a potential wholesale realignment of South African politics. Opposite are outlined four short- to medium-term possible leadership scenarios:

Four roads to more uncertainty

1. **Dlamini-Zuma wins the ANC presidency with the support of a bloc of votes carefully put together in concert with Jacob Zuma that does not rely solely on the so-called 'Premier League' and therefore gives Dlamini-Zuma some room to manoeuvre.** She is nevertheless hampered by nationalist factional baggage and their continuation of patronage politics, especially at provincial and local government levels. Although she provides sound technocratic managerialism, she lacks the leadership qualities necessary to bring vision and structural reform, or build a new social compact. The government continues to stumble along, 'at war with itself' as Ramaphosa has described it. Policy contradictions are perpetuated and even entrenched. Zuma may remain President of the country until 2019 and the prospect of the ANC polling at below 50% in the national elections becomes a very real one.
2. **The nationalists prevail, seizing control of both the ANC policy-making process in July and the NEC in December, and push the ANC into a new era of populist nationalism.** Dlamini-Zuma drops out or falls away and either an extreme candidate such as Supra Mahumapelo, David Mabuza or Ace Magashule (the 'Premier League' provincial premiers) emerges and, outflanking everyone, wins, or Zuma takes the 'Putin option' by standing for and winning a third term as ANC President and tries to rule from the back seat, and his rule becomes even more characterised by dictatorial tendencies. Either of those sub-scenarios will likely cause the ANC to split and South Africa to enter an even more unstable period, at least until the 2019 national election, whereupon the ANC would, in a free and fair election, lose its majority. A major realignment in South African party politics would unfold from 2018-2020.
3. **The constitutionalists representing the moderate middle and 'sensible' left of the ANC retain control of the policy-making process, and policy is merely 'recalibrated'.** Ramaphosa wins decisively and has the opportunity to build a new consensus between business, government and labour, based on a clear 'clean-up' and a sensible transformation mandate. Institutions of governance and state-owned companies are revitalised. A new era of inclusive growth is launched. Zuma is removed as President of the country in the early part of 2018 and the ANC retains a more than 50% majority in 2019.
4. **A compromise candidate emerges to heal the divisions in the ANC and hold the party together.** The contest between Nkosazana Dlamini-Zuma and Cyril Ramaphosa reaches a stalemate and threatens to tear the ANC apart. A compromise candidate, in order of probability, would be: Zweli Mkhize, Jeff Radebe, Gwede Mantashe or Lindiwe Sisulu. The ANC would struggle to recover lost political zest and trust with the electorate.

In any scenario, uncertainty is likely to remain reasonably high, while the political character of South Africa is also likely to become increasingly competitive. Democracy – South Africa style – will strengthen, as civil society and an independent media remain robust and the rule of law and an independent judiciary hold firm. As the ANC weakens further, multi-party democracy will become entrenched. The ANC will not dominate for much longer; different configurations of coalition government are likely to emerge as early as 2019, as the ANC disintegrates faster than expected (though much also depends on how adeptly the EFF and the main opposition party, the Democratic Alliance (DA), cope with the demands of coalition politics and minority government in Pretoria and Johannesburg over the next two years).

Can the ANC centre hold in 2019?

An ANC majority at the next national election in 2019 is no longer a foregone conclusion. Some in the ANC are concerned about the impact of failing to deal with Zuma before the 2019 national election. Former President Kgalema Motlanthe and Pravin Gordhan, among others, have warned of the serious possibility of the ANC losing power in 2019. The current crisis in the ANC has also prompted greater co-operation among opposition parties, perhaps fuelling an anti-ANC coalition in 2019. Already, opposition parties with some civil society role-players have established a broad-based 'Freedom Movement' as a precursor to such an alliance.

Implications for mining in South Africa

Julius Malema is South Africa's Nigel Farage or Donald Trump. The mood in South Africa, as in many other places around the world, is angry, turbulent and sprinkled with unusual, anti-establishment political figures that are capable and willing to exploit the frustrations of a working class that has been 'left behind'. South Africa faces a fast-growing clamour for populist solutions to deep-seated problems. The student protests on South African university campuses are likely to resume later in 2017, stoking the fires of violence and conflict in the face of an ill-prepared police service.

Each of the main political scenarios has significantly different implications for mining companies operating in South Africa:

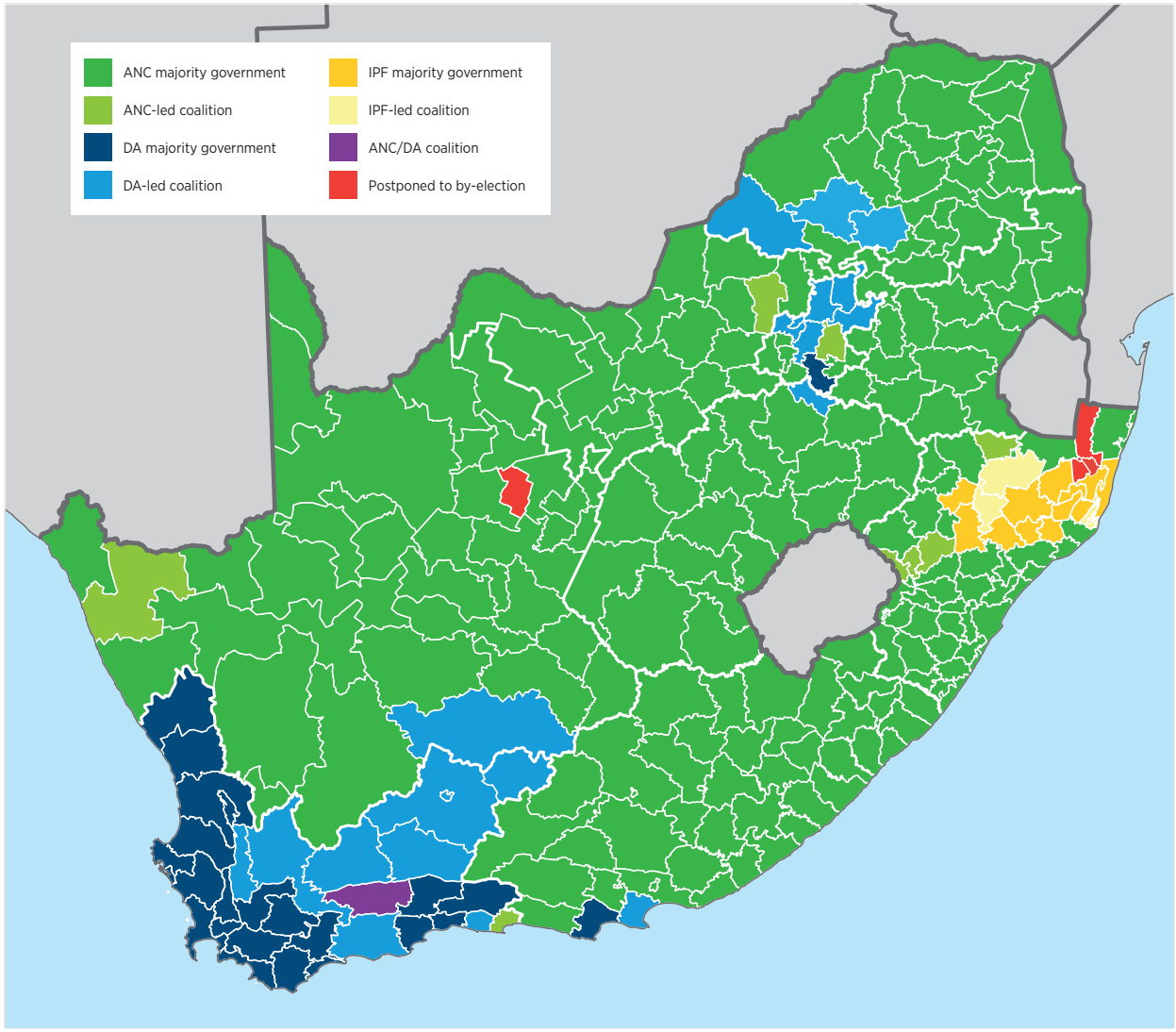
High, middle (muddle, and most likely) or low road for SA mining?

The high road scenario:

- South Africa transitions to an investor-friendly environment where mining law, labour law and a renewed social contract are conducive to long-term investment, on the back of a carefully facilitated and skillfully-led 'economic CODESA (Convention for a Democratic South Africa)'-style national dialogue involving the principal economic and social actors.
- The principle of 'once empowered, always empowered' is (re)established and greater certainty is provided to the market. Some significant structural reforms, such as strike ballots, are implemented and real progress is made on public education, skills and training.
- A national minimum wage is executed. Black Economic Empowerment (BEE) and transformation goals are clearly defined and Social Labour Plans become effective tools for trust-based social/community development.
- Calls for radical land redistribution recede as those calling for 'radical economic transformation' lose to the moderate reformers and constitutionalists in the ANC.
- Civil society robustly calls government to account and a clean-up of government agencies and state-owned companies builds confidence in a 'capable state'. The rule of law holds firm.
- As growth increases, public expenditure in the crucial areas of social welfare and public infrastructure is protected, as the national fiscus stabilises and the mining sector flourishes.
- The National Development Plan finally becomes the central pivot for government delivery and the international investment community begins to see South Africa as an attractive investment destination.
- Global blue chip mining companies compete to invest in Tier 1 mining projects, and they embrace an 'inclusive growth' model that recognises the need for socially conscious capitalism to be seen to be working for all members of society.

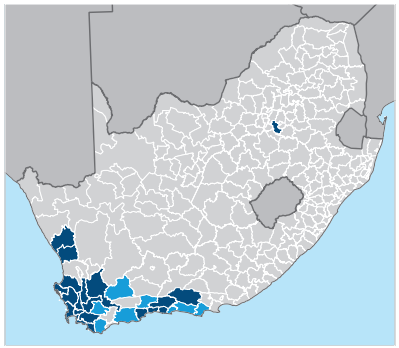
The probability of this scenario materialising is, however, at best moderate. Even with a Ramaphosa leadership victory, the political hurdles that would need to be navigated to successfully implement this scenario are substantial.

Coalition talks, 2016

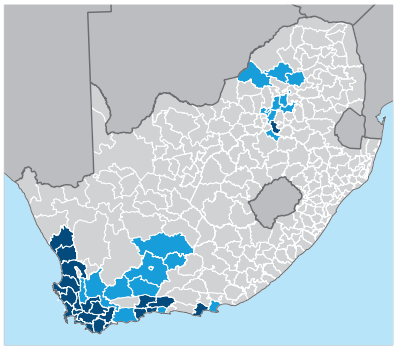


Source: The Paternoster Group

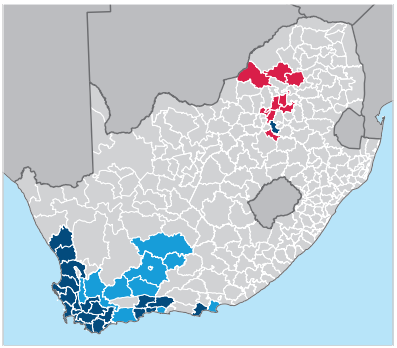
DA-led coalitions, 2011



DA-led coalitions, 2016



DA-led coalitions and minority governments, 2016



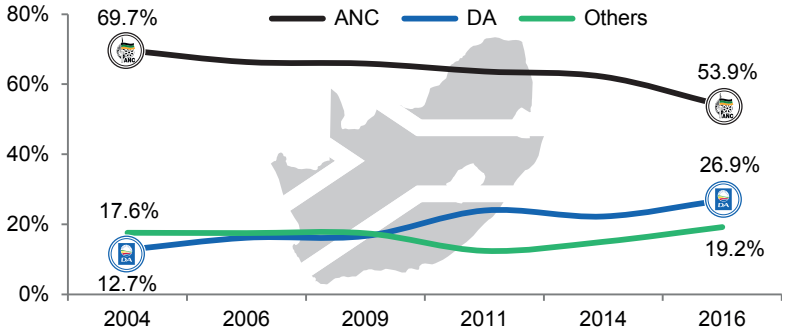
Source: The Paternoster Group

DA majority government

DA-led coalition

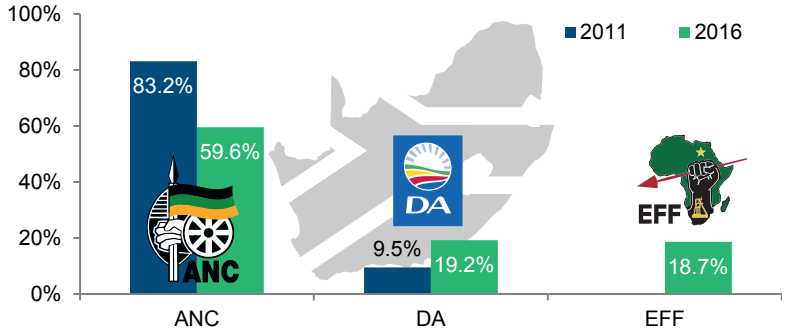
DA minority government relying on EFF support

Big picture trends



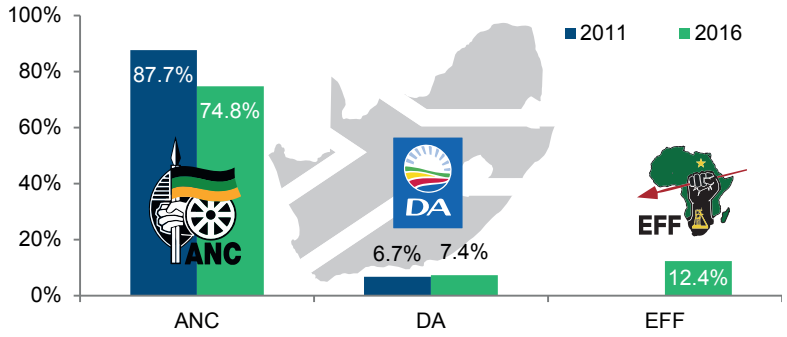
Source: The Paternoster Group

Electoral results in Tshwane – Mabopane (ward 21)



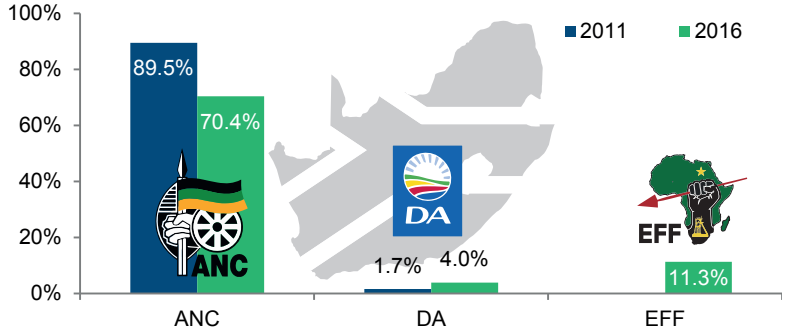
Source: The Paternoster Group

Electoral results in Johannesburg – Diepkloof (ward 26)



Source: The Paternoster Group

Electoral results in Nelson Mandela Bay – Motherwell (ward 56)



Source: The Paternoster Group

The middle road scenario:

- South Africa muddles along. Politicians do not have the courage to face down a populist backlash that would be likely to occur if there were a shift in mining policy to a more decisively investor-friendly direction. The contest for power between the nationalists and the constitutionalists in the ANC remains unresolved. Attempts to capture state institutions continue to be made, though less concertedly. Zuma's patronage network reconvenes under a different guise, but is at least partially contained.
- For the mining sector, there is continued regulatory uncertainty. Clarity about equity ownership levels and social and labour plan-type obligations remains elusive.
- Skills shortages will become even more pronounced as experienced executives once again start to look outside the country for career opportunities.
- Municipal incompetence and corruption, combined with escalating community unrest, will continue to make doing business difficult for miners.
- Days of lost production are very expensive and such incidents will become more frequent.
- No new quality investment can be justified and existing assets struggle to manage day to day. Their value gradually erodes like a slow puncture. Conspiracy theorists will speculate that this constant erosion of value is a deliberate ploy to enable assets to be transferred into black ownership at knockdown prices.

In the short and medium term this scenario is the most likely.

The low road scenario:

- Policy erosion, incompetence and corruption continue to snowball and the country becomes essentially un-investable (except to the rent-seeking corrupt) due to international market sentiment.
- The political context becomes so complex that obtaining government approval for major transactions will be difficult, undermining both investor confidence and operational integrity and limiting the strategic options available to mining houses. In this scenario, business that can easily be tarred with the 'white monopoly capital' brush will be the subject of repeated targeting – and hard, with increasingly personalised attacks on individual white business leaders. Companies with long histories in South Africa would inevitably be swept up in this, and attacks on those that try to re-domicile, or have already done so, will become more intense.
- Land redistribution would also emerge as a major policy imperative for government, on the back of a strong populist wave, putting further pressure on miners.
- The principle of 'once empowered, always empowered' is completely reversed and miners face new, more extreme demands. Day-to-day management is reduced to fire-fighting and despite all best endeavours, labour and community unrest becomes an entrenched regular feature. Employee and asset security risk is heightened.
- Asset ownership is gradually transferred into either, at best, inexperienced or, at worst, corrupt hands and within a decade, like the Zambian Copperbelt in the 1980s, the industry will be on its knees.

Unfortunately, this scenario has a reasonable probability.

Upside and opportunity

A glass that might be half-full may be shattered by ANC in-fighting

There is more space for meaningful government relations. Ironically, given the overall direction of travel and the deeply flawed and unpredictable nature of the Zuma presidency, government-business relations are "the best they've been for fifteen years", in the words of one banking sector CEO, although Gordhan's departure may now undermine this progress. The CEO Initiative that emerged from the disaster of Zuma's reckless '9/12' (9 December 2015) summary dismissal of the then Finance Minister Nhlanhla Nene has created space and opportunity for a more serious and meaningful dialogue, despite the political uncertainty and the contradictions within government, with increasing calls for an 'economic CODESA' (that would replicate the all-party talks of the early 1990s that led to South Africa's 'peaceful transition to democracy'). While Gordhan pulled up short of supporting such a call in the Budget speech in February, he teased the idea of including 'a charter of economic rights' – such as a right to work or a right to a basic income – in the legally guaranteed protection enshrined in the Constitution's Bill of Rights. This may be an important conversation to have; both ideas should be carefully considered, but the timing may not be opportune. The ANC and the government are just too bitterly divided and too preoccupied by power struggles and the succession battle. It would probably be best to wait until if and when Ramaphosa has taken power.

The state of the nation…is overextended already

Former Finance Minister Pravin Gordhan's Budget speech call for an 'inclusive growth' model echoes the global recognition that a new model of capitalism is required if long-term stability and prosperity are to be assured. An intelligent understanding of the limits of state power – as opposed to a rent-seeking, acquisitive approach to the use of state resources and state intervention in the economy – will inevitably settle on the need for consensus-finding between the key social and economic actors. The state – and Treasury, in particular – can only do so much. In the end, new, sustainable, decent employment will have to come from the private sector. The state is at its furthest reach in terms of its public works programme and its own contribution to employment; the public sector wage bill is at its outer limit and a fiscal cliff is fast approaching. So, logically, this means that the real conversation is about what the private sector needs government and labour to do or concede to enable it to employ more people. Since there are sharp divisions of opinion on this question, it seems that they can only be resolved through a carefully facilitated process of dialogue that builds mutual trust for the common good.

New thinking and bolder leadership are being seen across all sectors, including business. Never has the need for strategic collaboration and meaningful engagement between business and labour been greater, otherwise the grave danger is that no substantial or persuasive alternative narrative will be built to counter the compelling language and sloganeering of the populists.

THE PATERNOSTER GROUP – AFRICAN POLITICAL INSIGHT LTD

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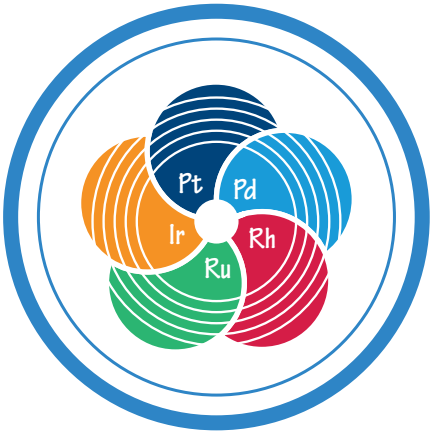
THE PGM MARKETS IN 2016/17



The PGM markets in 2016/17

Beresford Clarke and Dr. Jenny Watts, SFA (Oxford) Ltd

A minor [metal] uprising

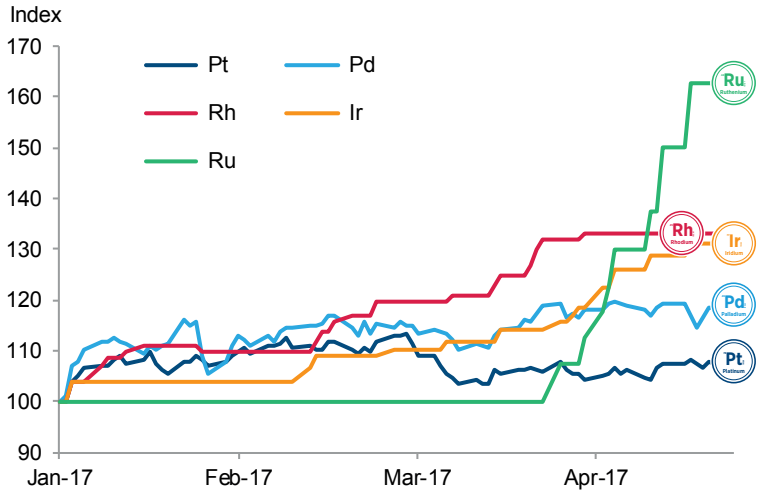
Minor PGMs (Rh, Ir, Ru) outperform majors

Of the quintuplet of PGMs (platinum, palladium, rhodium, iridium and ruthenium), it is the minor metals that appear to have been bought most aggressively this year. In a reflection of recent political outcomes, it is the extreme [metal] outsiders that are winning the [buyers'] vote. SFA has been inundated with industry and investor queries on the minor metals over the last few months, and for this reason SFA has prefaced an appraisal of iridium and ruthenium to the PGM market review.

(In case it seems that we missed out the forgotten PGM child osmium, the price for the metal remains dormant at around $400/oz, so is not yet justified for inclusion in the write-up.)

Prices of rhodium, iridium and ruthenium are up 33%, 31% and 63% respectively to $1,025/oz, $885/oz and $65/oz since the beginning of 2017. The palladium price has risen by 16% to $787/oz, while platinum is up 7% to $968/oz.

PGM prices this year



Source: SFA (Oxford), Bloomberg

Ru came alive at the end of March

All the minor metals are sold on contract, no terminal exchange, and are small, over-the-counter markets

What are the reasons for these dramatic price moves? Were some PGMs more depressed than others at the end of 2016? In this article, SFA will provide some clarity and guidance on the remainder of 2017 and just what is going on with the minor metals.

Catching the new mobility and technology wave?

Platinum, palladium and rhodium have long depended on the tailpipe catalysts of internal combustion engines for the majority of their demand. Iridium, too, has prospered from improvements in conventional automotive technology; it can be found on the electrode tips of the best spark plugs, to extract maximum efficiency from gasoline engines.

Ruthenium has, until now, had little presence in the automobile market, apart from small quantities used in electronic components, but several recent innovations may be set to change that – substantial industrial investment has been made in the production of battery materials.

Adoption zone pricing encourages innovation

As this market is increasingly buffeted by waves of uncertainty from legislative, political, public perception and energy quarters, so the materials requirements of the newer automotive technologies – in particular, battery electrification and fuel cells – may start to change the shape of 5E demand. The minor metals, in particular ruthenium, look set to be part of the enabling technology as transport transforms. With low metal pricing (in the adoption zone) and a very active research base, ruthenium has seen significant innovation leading to price recovery in the last few months. Of course, we should add a caveat that adoption of the minor metals has, in the past, been dogged by volatile pricing patterns in these small, opaque, over-the-counter markets.

Ruthenium catalysts in advanced Li-O_2 batteries

Ru may enable better batteries for EVs

Ruthenium has some potential to be used in advanced battery systems for electric vehicles. Ruthenium-based materials have been shown to be highly effective cathode catalysts in lithium-oxygen (Li-O_2) batteries, considered the most advanced battery system for future electric vehicles, and should enable Li-O_2 batteries to operate reversibly (formation/decomposition at the cathode upon cycling) with high efficiency and good cycling stability.

Non-aqueous Li-O_2 batteries are promising energy storage systems because of their very high energy densities, which are significantly greater than those of the currently mainstream lithium-ion batteries. Recently, carbon materials have been widely used as cathode catalysts for Li-O_2 batteries because of their outstanding conductivity. However, side reactions led to degradation in the cycling performance, reducing the commercial viability of such batteries.

Research teams at academic institutions in Japan, China, Australia and elsewhere are active in improving the electrical energy efficiency through better choice of the electrode materials.

Several ruthenium-based approaches have delivered promising results under laboratory conditions.

Ruthenium oxide nanoparticles dispersed on multi-walled carbon nanotubes as a cathode have been shown by a Japanese team to substantially increase electrical efficiency. A Chinese team has developed a 3D mesoporous graphene-like carbon structure on which a uniform layer of ruthenium particles was grown. An Australian team has developed catalysts of ruthenium nanocrystals supported on carbon black.

Ruthenium catalysts for hydrogen generation?

Early stage work shows Ru enabling fuel cell market

An academic group in South Korea has developed a new catalyst, claiming it can split water into hydrogen and oxygen almost as well as platinum. Announced to the press in mid-February 2017, this ruthenium-based material works almost as efficiently as platinum and, importantly, appears to show the highest catalytic performance and be less affected by the acidity of the water, potentially making it more resilient and reliable in real-world use.

Current platinum-based catalysts are inevitably costly and are also less stable in an alkaline environment. Research has been directed towards creating catalysts from cheap, non-noble metals, but these materials corrode rapidly under certain conditions and operate at very high voltages, so their productivity is limited.

The group has synthesised ruthenium and C2N, a two-dimensional organic structure, and with the novel catalyst, named Ru@C2N, found it was possible to produce hydrogen efficiently. The material is claimed to satisfy all four commercial requirements of water-splitting catalysts; it exhibits high turnover frequency; it can be operated on low-voltage supply; it is not affected by the pH of the water; and it can be used in any environment.

Sales of Pt-bearing fuel cells need easy hydrogen production

The synthetic route to Ru@C2N is simple, which increases its potential commercial viability. The ruthenium salt $RuCl_3$ is mixed with the monomers to form the porous, two-dimensional organic structure, C2N. The final Ru@C2N catalyst is then produced after reduction and heat treatment processes.

The same process was used to make analogues with cobalt, nickel and platinum; comparing their efficiency of hydrogen production, the Ru@C2N catalyst showed the highest catalytic performance at the lowest overvoltage, as well as high catalytic activity.

Communication and electrification 'megatrends' boost iridium and ruthenium uses

Iridium demand has for several years been mainly from crucibles for forming electronic materials, principally lithium tantalate and lithium niobate for communications technology. They are used for wafers for SAW filters, demand for which is driven by growth in wireless device usage.

In smartphones and other mobile devices, SAW filters are responsible for tuning into specific frequency bands and blocking interference from other signals. With enough filters, devices can simultaneously communicate over Wi-Fi, Bluetooth, and cellular bands used in 3G and 4G networks. As wireless technology breaks into higher frequency spectra, the number of filters per device is steadily rising. The global radio frequency (RF) filter market is expected to maintain double-digit growth over the next few years.

Lithium tantalate substrate production capacity is growing in response to requests from SAW filter manufacturers. Sumitomo Metal Mining Co. (SMM) plans to expand substrate output by around 33% in 2017. Some of the industry-wide capacity expansion for producing lithium tantalate substrate may not be reflected in iridium purchases for crucibles as some overcapacity may have existed in crucibles for sapphire substrate production for LEDs, and these may be re-purposed for lithium tantalate production.

Ir crucibles enable key materials for mobile technology

Inevitably, there are some risks to crucible demand, with iridium exposed to threats beyond its control – molybdenum is a lower cost competing crucible material, though it can be difficult to form. However, iridium crucibles last longer under the hostile chemical and thermal environment in which they operate, so the substitution threat is limited at present.

Chip resistors are set to overtake hard disks as ruthenium's main electrical application. Resistors are ubiquitous in electronics, and this is a growing market.

Connected and autonomous vehicles set to boost chip resistor demand

Chip resistors are primarily used to create and maintain a known safe current within electrical components. They are employed in a vast range of products, including servers, printers, telecoms, consumer electronics, automotive electronics, industrial applications and power systems. General purpose thick-film chip resistors are the most prolifically-used part in electronic and electrical devices; a typical PC contains >1,200 chip resistors.

Thick-film resistive elements start with a grain-containing ruthenium oxide paste, mixed with a fusible glassy binder which is screen-printed onto a ceramic substrate, then fired. Modern resistor pastes are based (in volume order) on oxides of ruthenium, iridium and rhenium.

Thick film is preferred over thin film since the manufacturing process is much cheaper and the performance is adequate for all but the highest precision applications such as in medical devices, precision controls and measurement devices.

The ruthenium content in chip resistors has, like most PGM applications, suffered limited bouts of thrifting and demand destruction from on-going miniaturisation of components. However, these effects are far outweighed by the increased use of components in end-products and the growth in the number of electrical/electronic products.

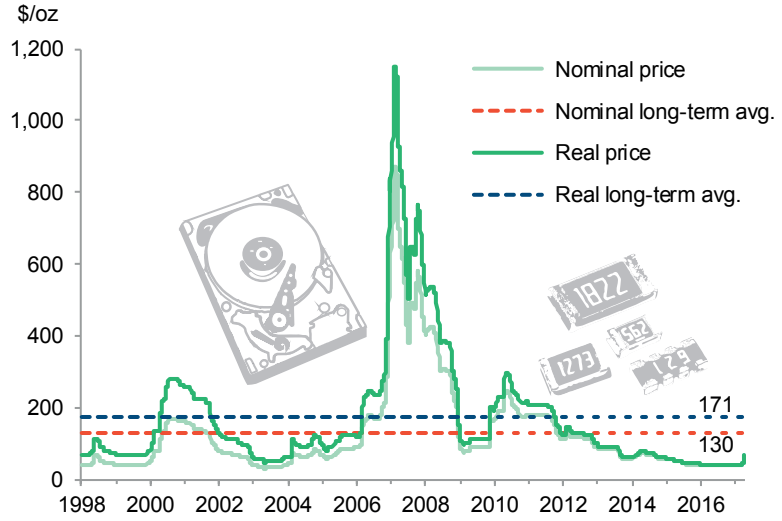
Ruthenium price rapidly outperforms in Q1'17

Ru remains good value for industrial users

Analysis of historical price data shows that even today's price of $65/oz (nominal), up from $40/oz in less than a month, is still comfortably below the long-term averages of $130/oz (nominal) and $171/oz (real), suggesting that ruthenium remains good value for industrial use.

The ruthenium price had been below $50/oz for nearly two years, sitting at $42/oz between July 2015 and October 2016, before dipping to $40/oz, then beginning its rise on 27 March 2017. The nominal price has been below the real long-term average since September 2011, making the development of new demand areas attractive. Sharing some of the same physical and chemical properties as platinum, ruthenium potentially presents a cost-effective alternative in certain applications.

Historical ruthenium prices



Source: SFA (Oxford), Bloomberg

Despite recent increases, prices are well below historical averages

The Pt:Ru price ratio, similarly to the widely used Pt:Pd ratio, can help to indicate the potential for price-driven substitution in end-uses. The recent price hike takes the ratio to 15.1, very close to the 10-year average of 14.7 but still some way from the long-term (since 1998) average of 12.2.

Significant and sustained price rises would reduce the attractiveness of ruthenium compared to platinum, palladium and rhodium, though with more than 10x price differential, it would take time to erode ruthenium's price advantage. Ample producer and fabricator stocks – at least a year's worth of current demand – are believed to exist, further reducing pressure from ruthenium prices. Of course, rising prices should trigger increased recycling activity, where technically feasible.

Platinum-ruthenium price ratio

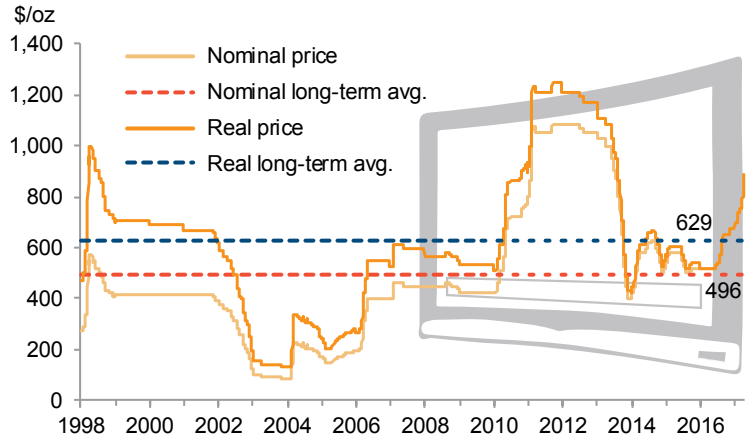
Source: SFA (Oxford), Bloomberg

10-year Pt-Ru price ratio average higher than the long-term average

Iridium approaches parity with platinum

Iridium has been third only to ruthenium and rhodium in its price appreciation so far this year, up from $700/oz at the beginning of 2017 to just below $900/oz at present. Unlike ruthenium, iridium saw substantial price appreciation through 2016, up from $520/oz at the beginning of the year to $675/oz by the end. Much of the rise was attributed to capacity expansions for lithium tantalate production for SAW filters, mainly in Japan. The real iridium price broke through the long-term average in August 2016, in the midst of the crucible buying, potentially taking it further out of the adoption zone for new uses.

Historical iridium prices



Source: SFA (Oxford), Bloomberg

The Ir price is rising sharply again

The Pt:Ir price ratio might indicate that there could be further scope for substitution – spark plug tips being the main common ground.

Platinum-iridium price ratio

Source: SFA (Oxford), Bloomberg

THE RUTHENIUM MARKET

The Ruthenium Market report offers a robust, independent outlook for this niche strategic commodity. It provides a granular overview of the technological developments and underlying evolution of demand and end-use applications – electrical, chemical catalysis, electrochemical, and aerospace.

The main application, namely higher-density data storage (electrical demand), is covered in detail, in particular: manufacturing bases, players and regions; price and performance drivers encouraging the use of ruthenium; and threats to ruthenium at current prices (substitution, new technologies).

Electrical demand

- Use of ruthenium in hard-disk drives (HDD)
- Technology evolution and main players
- Technology substitution threats from solid-state drives (SSD)
- Forecast memory capacity requirements and HDD manufacture
- Impact of changing technology on ruthenium demand outlook

Electrochemical demand

- Industrial process requirements of anodes coated with PGMs
- Chloralkali products and output, growth, capacity requirements and PGM top-up requirements

Chemical demand

- Forecast regional production of ammonia and acetic acid
- CATIVA™, KAAP™ and Grubbs catalyst technologies
- Technology evolution: growth and substitution threats
- Installed capacity versus production outlook
- Forecast demand for ruthenium from new plant capacity and top-up requirements

New applications and potential upside

- Aerospace, environmental legislation and the economics of using ruthenium in turbine blades
- Fuel cells: technologies, outlook, potential hydrogen requirements and opportunities for ruthenium use in catalysts

Ruthenium supply and stocks

- Forecast (primary) supply, by producer and by region
- Reserve and resource depletion analysis
- Estimated stocks (stockpiles, working inventories), producers, traders and recyclers, and quantification of unrefined stock
- Stocks in weeks of demand

Pricing of ruthenium

- Pricing trends out to 2022

For more information please contact David Mobbs (dmobbs@sfa-oxford.com).

THE IRIDIUM MARKET

The Iridium Market report provides a short- to medium-term supply, demand and price forecast in a focused outlook for iridium end-use applications (existing and future), in particular: LEDs, biomedical, jewellery, automotive and catalysis; manufacturing and fabrication bases, players and regions; price and performance drivers encouraging the use of iridium; threats to iridium (within substrate, tooling sector) at current prices (substitution by molybdenum and tungsten etc.); new technologies; and opportunities for iridium growth in new LED applications (automotive, industrial and residential lighting, signs, etc.) and chemical demand.

Electrical demand

- The LED market: new technology, energy efficiency, costs and market share
- Demand growth and capacity builds for LED TVs and lighting
- The iridium crucible market and the role of sapphire in LED production
- Gallium nitride (GaN) on sapphire versus GaN on silicon
- The threat of substitution from molybdenum and tungsten in high-temperature melting applications
- Iridium demand for crucibles used in LED production
- Outlook for OLED displays and potential impacts on iridium demand

Electrochemical demand

- The chloralkali process and iridium demand
- Substitution of a mercury-based process by an iridium-based process

Automotive demand

- Automotive demand for iridium-tipped spark plugs
- Substitution threats from molybdenum

Chemical demand

- The CATIVA™ process and acetic acid demand, including capacity requirements

For more information please contact David Mobbs (dmobbs@sfa-oxford.com).

Other demand

- Jewellery
- Medical
- Novel end-uses

Iridium supply and stocks

- Forecast (primary) supply, by producer and by region
- Reserve and resource depletion analysis
- Industry stock levels
- Movements of stock by producers and quantification of unrefined stock
- Stocks in weeks of demand

Pricing of iridium

- Pricing trends out to 2022

The platinum market

Summary

The platinum market shifted into industrial surplus of 115 koz in 2016 after the preceding two years of market shortfall caused by the mineworker strike in South Africa in 2014. Apart from 2014 and 2015, there has been a cumulative industrial oversupply of over 2 moz of platinum into the market since the financial crisis in 2008.

An industrial market surplus of 115 koz in 2016

Nonetheless, that 'oversupply' of metal could be treated as *metal available for investment*, and over the same period we have seen the rise of ETFs (an increase in holdings of 2.2 moz) and a recent flurry of bar buying by the general public in Japan which has consumed a net amount of over 800 koz in the last two years. So after investment, it could be said that the platinum market has been in deficit.

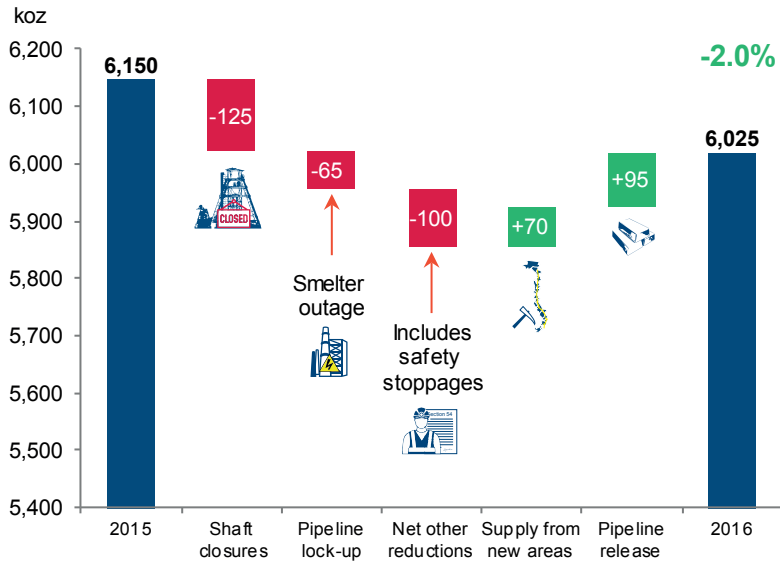
To avoid any confusion, SFA's barometer is the industrial balance, by which we measure the health of our 'industry'. After all, it is the underlying trends in individual segments of the market that will dictate investment and the price.

Mine supply

Global platinum production fell by 2% to 6.0 moz in 2016. The decline was primarily due to shaft closures and safety-related stoppages in South Africa, where mine supply fell by 5% to 4.2 moz.

Mine supply fell 2% year-on-year

Change in global platinum supply



Source: SFA (Oxford), Bloomberg

Shaft closures and safety stoppages impacted supply in 2016

Low PGM prices started to bite, with shaft closures responsible for a loss of around 125 koz. These were primarily UG2 Reef mining operations with a higher exposure to low PGM prices (especially rhodium) and a limited revenue contribution from base metal by-products of nickel and copper, as yielded from other ore bodies, to offset weaker PGM prices.

Operating conditions underground were extremely challenging in 2016, with estimated safety stoppages of between 150 and 200 notices. A number of companies reported a double-digit increase in the number of interventions.

Supply from Russia was largely flat, while output from Zimbabwe and North America grew, helping to offset some of the loss from South Africa.

Recycling

Autocatalyst recycling almost recovered

The recovery of platinum from recycled sources has been tumultuous over the last two years. Having peaked in 2014 at 2.0 moz, volumes were impacted in 2015 mainly by a reduction in scrap jewellery, but also by a hiccup in the growth of recycled scrap catalytic converters.

The steady revival in the prices of scrap steel and PGMs helped recycling to recover by 9% to 1.9 moz in 2016. Jewellery recycling was up 21% to 625 koz as weak retail sales and excessive stock boosted jewellery returns. Autocatalyst recycling was only an estimated 20 koz shy of 2014 levels at 1.2 moz, with the majority of the recovery arriving in the second half of the year.

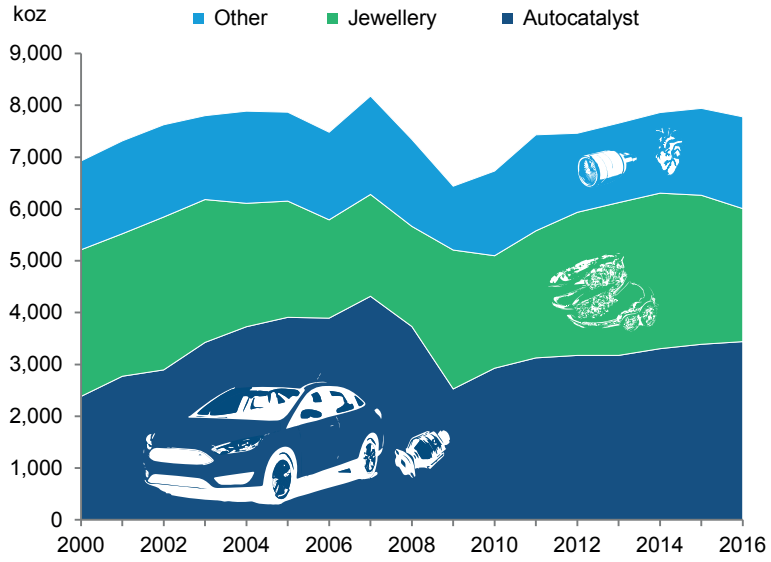
Demand

Global demand for platinum dropped 2.1% to 7.78 moz in 2016 (excluding investment buying) – the first annual reduction since the financial crisis.

The main culprit was not the demise of platinum-rich diesel vehicles in Europe, as might be expected. In fact, Western Europe's demand for platinum was up 55 koz to 2.15 moz. Tighter emissions legislation (Euro 6) leading to higher platinum loadings helped to raise overall consumption.

The cause of the decline in platinum demand was a 280 koz reduction in China's use, slipping to 2.16 moz. Jewellery demand, in particular, was down by 355 koz to 1.41 moz, having peaked at 1.99 moz in 2013.

Platinum demand by key application



Source: SFA (Oxford), Bloomberg

Weaker jewellery demand impacts the total for 2016

Automotive demand

Global automotive demand for platinum held up during 2016, growing 1% year-on-year to 3.44 moz. Western Europe was the major pillar of catalytic converter use. A drop in diesel passenger car shares knocked output by fewer than 200,000 units, but overall (when including light and heavy commercial vehicles) the number of diesel vehicles remained flat, so it was the higher loadings associated with Euro 6 emissions legislation that helped to boost demand by 90 koz to 1.65 moz in 2016.

Growth in other regions was limited. Demand from North America fell by 45 koz to 430 koz as manufacturing of both diesel passenger cars and heavy-duty vehicles was lower.

Jewellery demand

Total requirements for platinum in jewellery were down 11% to 2.57 moz in 2016. A collapse in demand in platinum jewellery's largest market, China, was the primary cause. Fabricator purchasing there was down by a fifth to 1.4 moz as poor retail sales growth and excessive metal stocking in late 2015 weighed on the market in 2016.

Collectively, demand from other regions grew by 3.6%, but added only 40 koz. Sales in North America and India continued to rise, albeit from a much lower base relative to China.

Industrial demand

New oil refining capacity lifts industrial demand

Industrial consumption rose by 6% to 1.78 moz, primarily due to a sharp increase in petroleum sector metal requirements. Petroleum use was estimated at 220 koz in 2016, compared to 140 koz in 2015.

Major expansion in catalytic reforming capacity in both Canada and the USA was the key driver, particularly after lacklustre demand in 2015. Among other uses, steadily growing requirements for fuel cells in Japan and a step-up in the use of automotive sensors in China boosted platinum demand further.

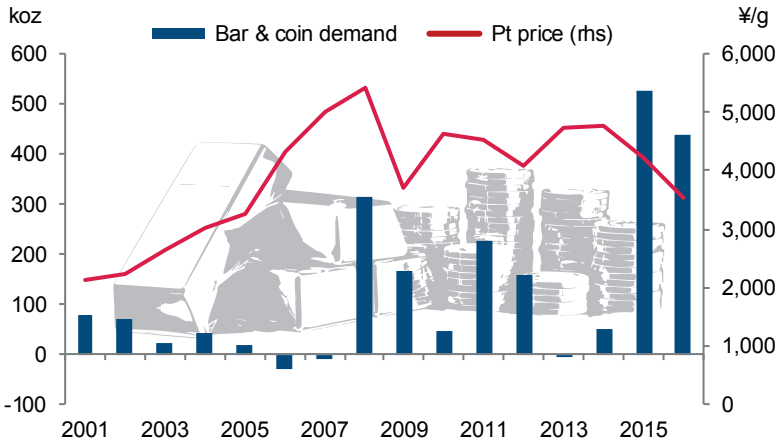
Investment and movement of above-ground stocks

While there were individual swings in regional ETF holdings, the total net change for the year was almost flat, with just 8 koz of outflows, leaving total holdings at 2.5 moz.

The major investment story for 2016 was once again general public bar purchasing in Japan. Global bar and coin investors there added a net 440 koz during the year. This was a drop from the exceptional 525 koz absorbed in 2015, but a phenomenal amount by historical standards. A platinum price discount to gold and a weakening yen provided a strong investment case for platinum in Japan.

Platinum bar and coin demand

Bars and coins absorb a net 440 koz in 2016



Source: SFA (Oxford), Bloomberg

A weaker platinum price in the early part of 2016 helped to shift sponge stocks into Europe, particularly in the second quarter, which goes hand-in-hand with a switch to a sponge-ingot premium at the time of over $2/oz. A platinum price recovery in the second half alleviated stronger buying in Europe and sponge premiums returned to zero. Nonetheless, trade into Europe was still up around 5% year-on-year. Overall metal lease rates ticked up slightly, but not enough to suggest a tight market.

The palladium market

Deficit widens...

The market continues to draw down stock at a rapid rate but 2016 was exceptional with an estimated industrial deficit of 1.27 moz.

...and investors pile out

However, investors in ETFs piled out, with holdings dropping by 640 koz, a consecutive year of +600 koz redemptions. This would leave the market at a net deficit of 625 koz after changes to ETF holdings if that is how you 'slice and dice' market fundamentals. However, we believe metal sold from ETFs was happily absorbed by industrial users and strategic holders, as prices ended the year around $130/oz higher than at the start.

Auto sales growth ensures strong demand

A combination of 13% growth in light-vehicle sales in China, record sales in the USA, and strong gasoline car sales in Europe helped to lift automotive demand by 260 koz in 2016 to 8.0 moz.

Light-vehicle sales in China achieved the strongest growth in three years, with sales up 3.3 million units to 28.2 million vehicles. Sales were lifted by a consumer rush to beat an anticipated tax rise on vehicles with less than 1.6-litre engines. Tax on cars with smaller engines was halved from 10% to 5% in October 2015 through to December 2016 to reignite demand. The Chinese government lifted the tax to 7.5% in January 2017, still an overall 2.5% tax discount.

Non-automotive demand, which accounts for 22% of the annual total, remained flat in 2016. A slight drop in jewellery, electrical and dental requirements was offset by a rise in chemical demand.

Chemical sector demand in China and the RoW was bolstered by production capacity expansions in hydrogen peroxide and purified terephthalic acid, with China in a bid to become more self-sufficient in bulk chemicals.

Overall supply plateaued at 9.03 moz:

- Primary production dropped 2.0% to 6.80 moz owing to reduced output from South Africa (-7.8% to 2.36 moz) and Russia (-1.9% to 2.56 moz), which offset growth in North America and Zimbabwe.
- Recycling was up 3.7% year-on-year at 2.23 moz, but was still recovering from a 6% fall in 2015, so was only back to 2013 levels.

The rhodium market

The industrial balance switched to a slight surplus of 30 koz in 2016. Consumption remained relatively stable at 1.02 moz, but buying in China ratcheted up towards the end of the year, perhaps ahead of requirements in 2017 as emissions legislation was due to tighten. This most likely helped the price to increase by $110/oz over the year.

Industrial usage was boosted by 15 koz to 185 koz owing to an increase in glass fibre capacity in China and the USA.

Unlike platinum and palladium, rhodium automotive recycling moved just ahead of 2014 levels owing to the mix of catalysts returning to market and slightly higher loadings.

Mine supply remained stable, with a slight drop from South Africa being offset by a rise in Zimbabwe.

The price outlook for the next six months

Platinum $950/oz

Price influence from market fundamentals is limited, but supply risks are mounting

The industrial market is essentially in equilibrium and lease rates remain low, so the influence of fundamentals on price direction this year is limited. Supply risks are growing, however, which could lift prices from the current forecast.

A price that remains close to the 80th centile of the producer cost curve is likely, with external influences from gold prices and rand-dollar exchange rates playing a part in the volatility of the dollar platinum price in H2 as well. A dollar price of around $950/oz is fair value for platinum in 2017, unless supply is impacted.

Palladium $775/oz

Price parity with platinum is in sight, but it is happening too fast...

Based on firm fundamentals, and stickier stocks leading to a pick-up in lease rates, palladium prices continue to rise.

Prices have appreciated through April to over $800/oz. Worldwide auto sales were up over 5% in Q1 compared to last year and buyers in China were not put off by a tax hike in January, with sales also up over 5% year-on-year. Even in Western Europe, sales managed over 7% growth. Only the USA, where many believe sales reached record levels in 2016, saw a drop of 1.4% year-on-year.

...and a price correction is possible

However, for the year as a whole vehicle sales growth in China is forecast to soften from last year's double-digit growth rates. Therefore, a combination of slower sales in both China and the USA should put the brakes on palladium's rally in the near term. Expect a temporary reversal in H2, unless a supply correction is forthcoming or China surprises to the upside.

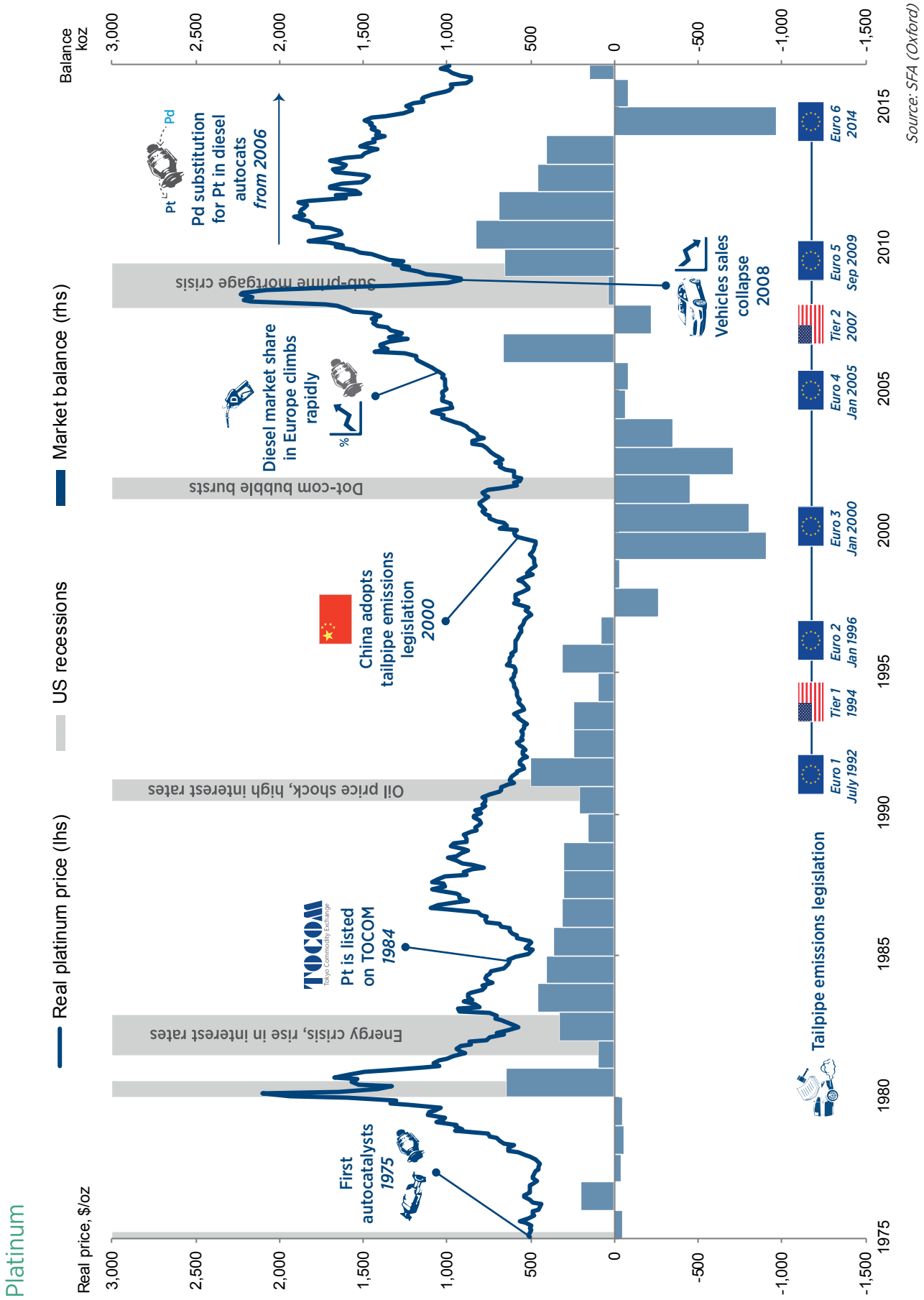
Unless palladium is substituted to other PGMs, prices should trade towards parity with platinum, but this will take time as stocks are sizeable. On this basis, the recent narrowing of the ratio is happening too fast and appears temporary (unless the rand collapses, of course).

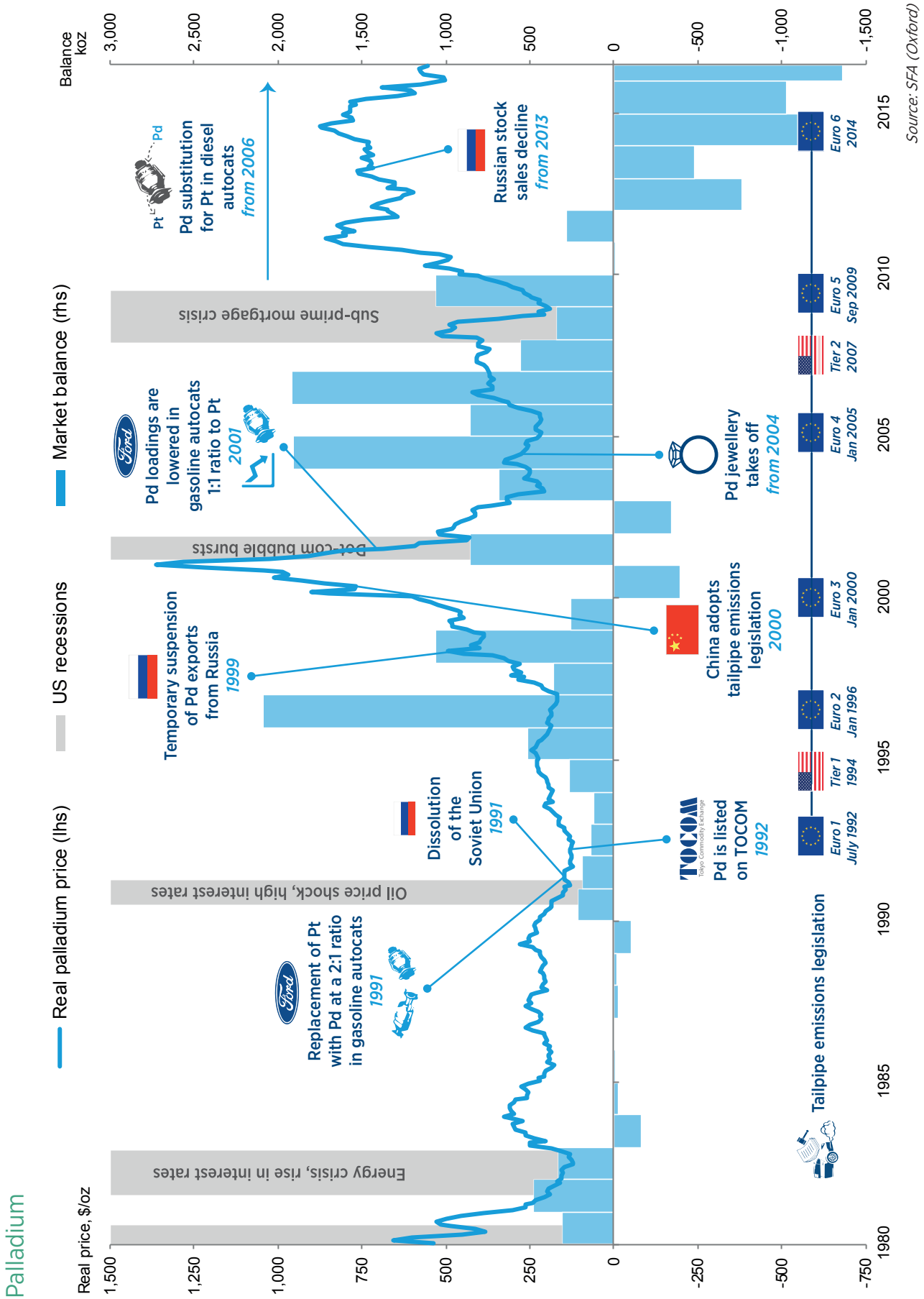
Rhodium $1,000/oz

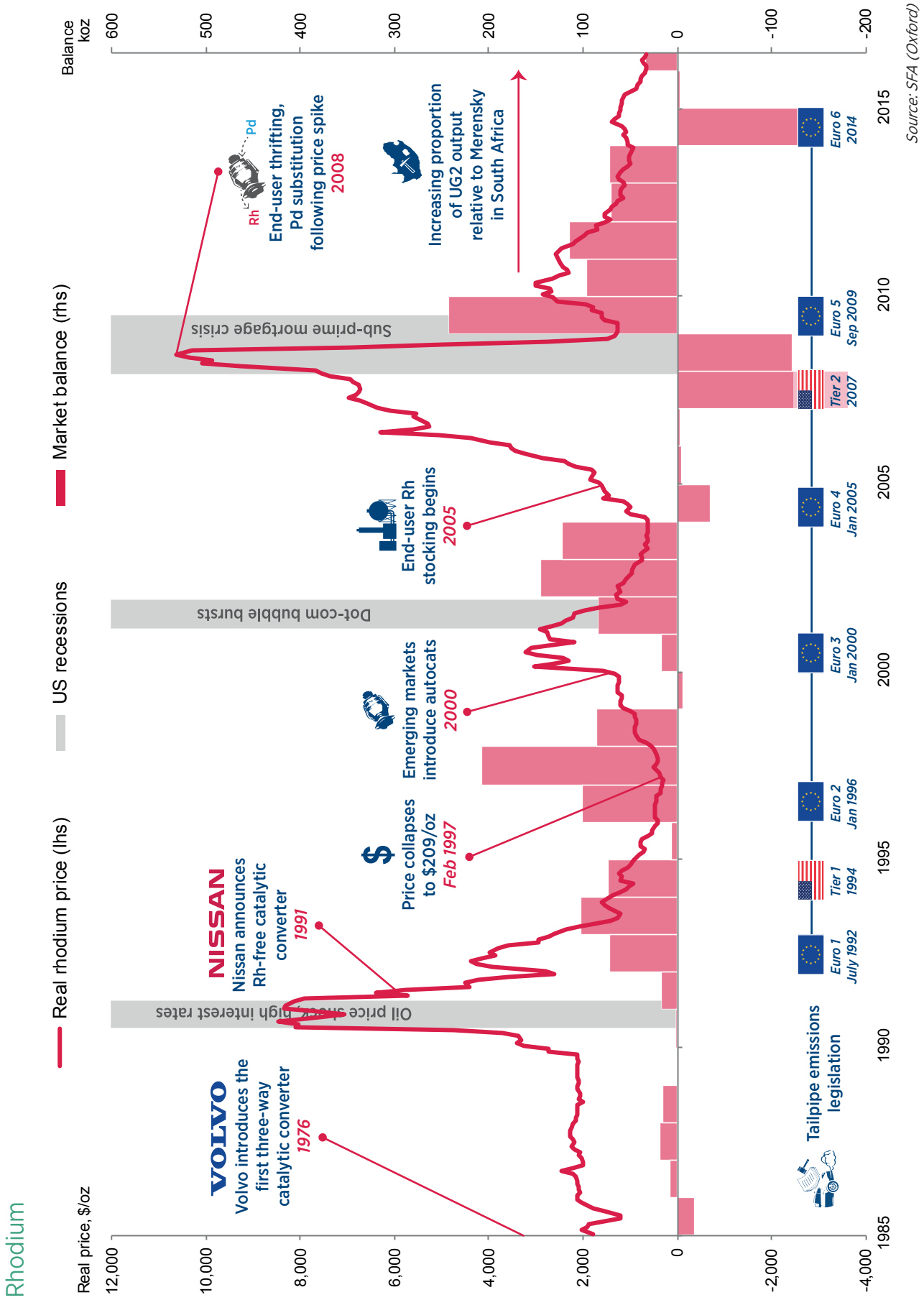
Possible supply disruptions could further stiffen the price

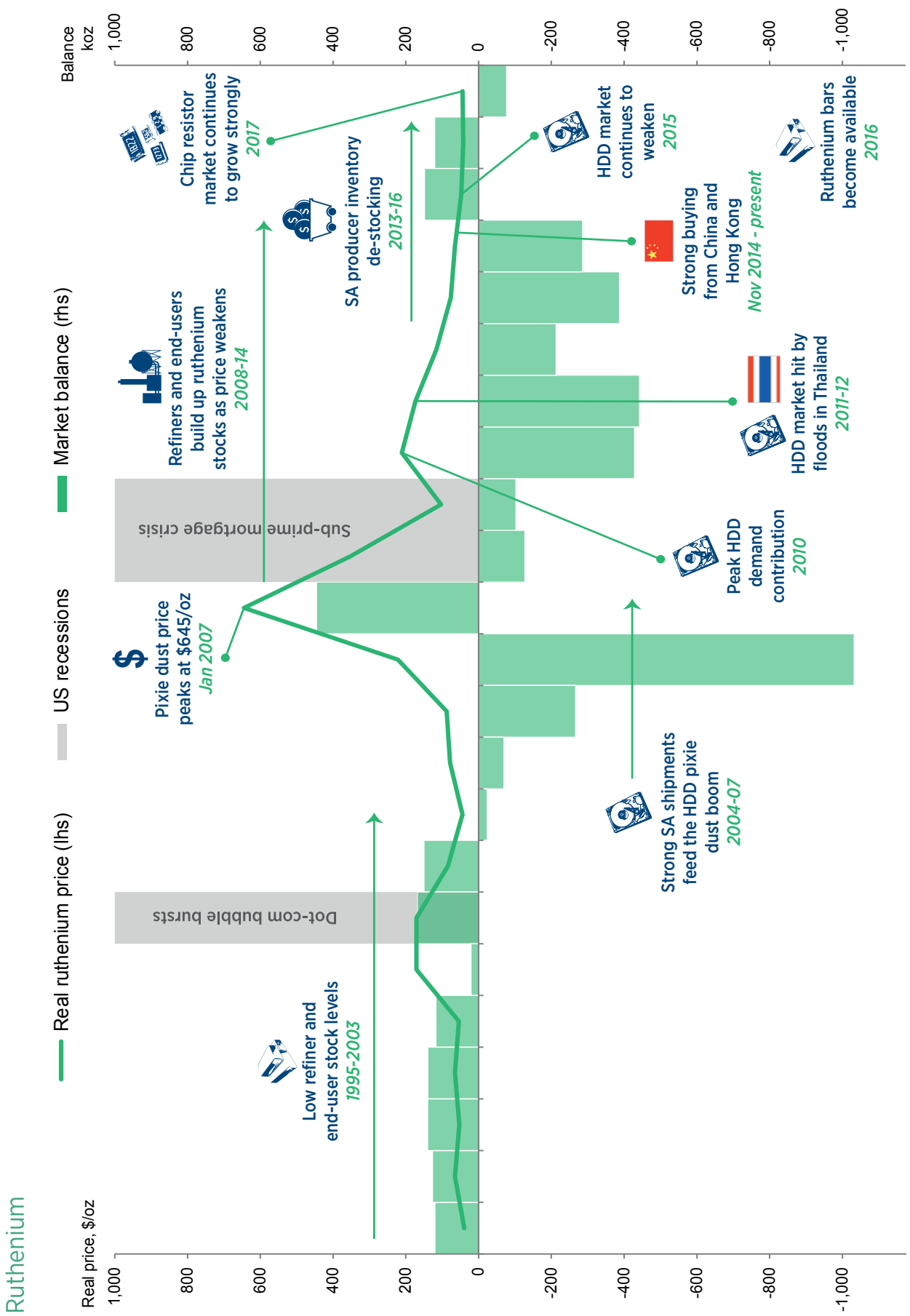
A small market of only 1 moz can easily lead to price volatility, as has been seen in the past. Strong gasoline car sales in China and the USA have boosted the need for rhodium, with shipments picking up towards the end of 2016 and into 2017. Increasingly stringent emissions legislation (compounded by auto companies not wanting to be seen to be cheating on gasoline tests), and a focus on vehicle NO_x output, should ensure steady buying of rhodium and support the price at around $1,000/oz. The market is well supplied, but any disruptions to supply could stiffen the price in the near term if stocks become illiquid.

PGM PRICE HISTORY

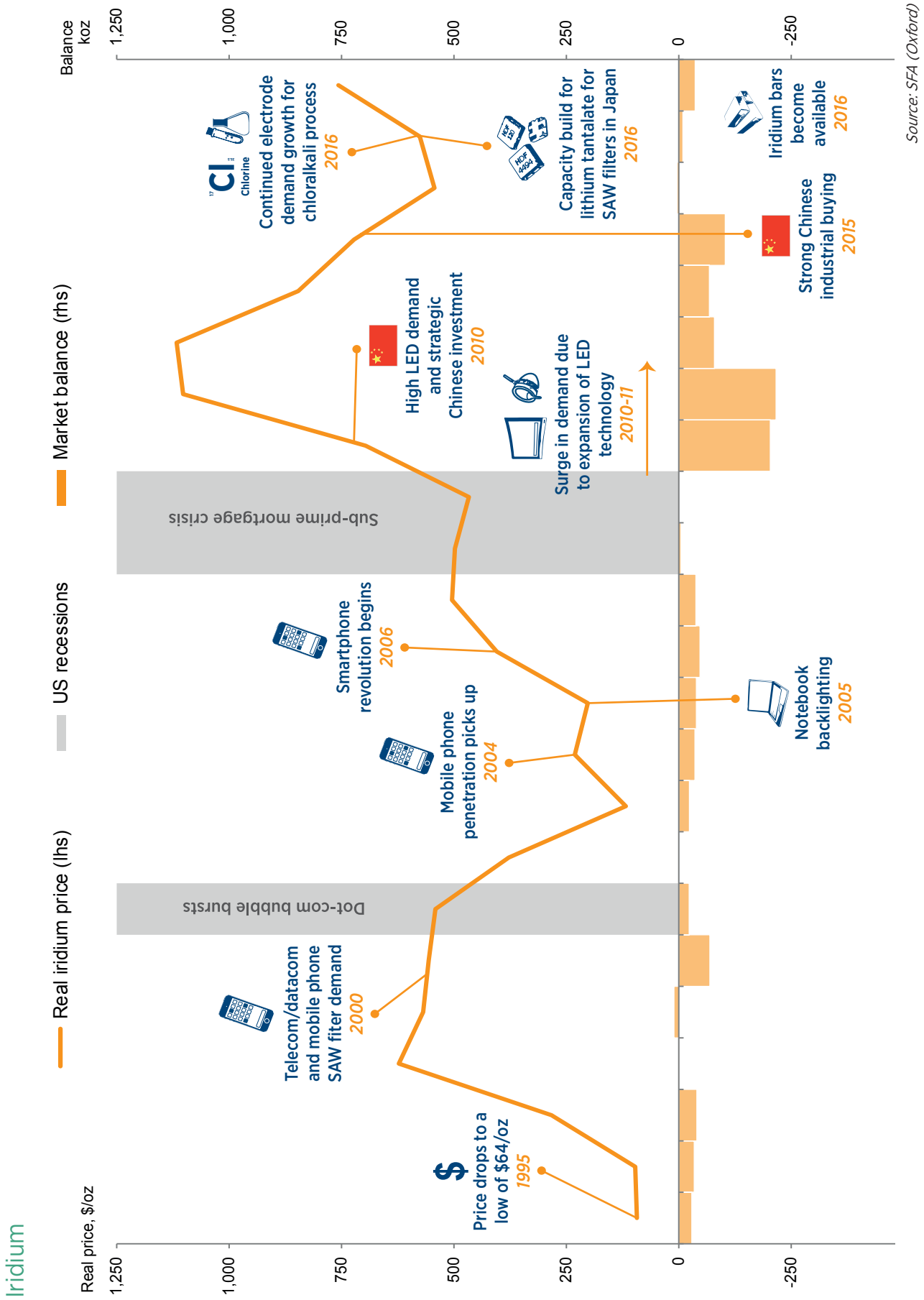

Platinum
Real platinum price (lhs)
US recessions
Market balance (rhs)
Real price, $/oz
Balance koz
3,000
2,500
2,000
1,500
1,000
500
0
-500
-1,000
-1,500
1975
1980
1985
1990
1995
2000
2005
2010
2015
First autocatalysts 1975
Energy crisis, rise in interest rates
TOCOM Tokyo Commodity Exchange
Pt is listed on TOCOM 1984
Oil price shock, high interest rates
China adopts tailpipe emissions legislation 2000
Dot-com bubble bursts
Diesel market share in Europe climbs rapidly
Sub-prime mortgage crisis
Pt
Pd
Pd substitution for Pt in diesel autocats from 2006
Vehicles sales collapse 2008
Tailpipe emissions legislation
Euro 1 July 1992
Tier 1 1994
Euro 2 Jan 1996
Euro 3 Jan 2000
Euro 4 Jan 2005
Tier 2 2007
Euro 5 Sep 2009
Euro 6 2014
Source: SFA (Oxford)


Real palladium price (lhs)
US recessions
Market balance (rhs)
Real price, $/oz
Balance koz
Energy crisis, rise in interest rates
Oil price shock, high interest rates
Dot-com bubble bursts
Sub-prime mortgage crisis
Tailpipe emissions legislation
Euro 1 July 1992
Tier 1 1994
Euro 2 Jan 1996
Euro 3 Jan 2000
Euro 4 Jan 2005
Tier 2 2007
Euro 5 Sep 2009
Euro 6 2014
Replacement of Pt with Pd at a 2:1 ratio in gasoline autocats 1991
Dissolution of the Soviet Union 1991
Temporary suspension of Pd exports from Russia 1999
Pd loadings are lowered in gasoline autocats 1:1 ratio to Pt 2001
Pd substitution for Pt in diesel autocats from 2006
Pd is listed on TOCOM 1992
China adopts tailpipe emissions legislation 2000
Pd jewellery takes off from 2004
Russian stock sales decline from 2013
Source: SFA (Oxford)


Rhodium
Real rhodium price (lhs)
US recessions
Market balance (rhs)
Real price, $/oz
Balance koz
12,000
10,000
8,000
6,000
4,000
2,000
0
-2,000
-4,000
600
500
400
300
200
100
0
-100
-200
1985
1990
1995
2000
2005
2010
2015
Source: SFA (Oxford)
VOLVO
Volvo introduces the first three-way catalytic converter
1976
Oil price shock, high interest rates
NISSAN
Nissan announces Rh-free catalytic converter
1991
$
Price collapses to $209/oz
Feb 1997
Emerging markets introduce autocats
2000
Dot-com bubble bursts
End-user Rh stocking begins
2005
Sub-prime mortgage crisis
Rh
Pd
End-user thrifting, Pd substitution following price spike
2008
Increasing proportion of UG2 output relative to Merensky in South Africa
Tailpipe emissions legislation
Euro 1
July 1992
Tier 1
1994
Euro 2
Jan 1996
Euro 3
Jan 2000
Euro 4
Jan 2005
Tier 2
2007
Euro 5
Sep 2009
Euro 6
2014



Source: SFA (Oxford)


Iridium
Real iridium price (lhs)
US recessions
Market balance (rhs)
Real price, $/oz
Balance koz
1,250
1,000
750
500
250
0
-250
Dot-com bubble bursts
Sub-prime mortgage crisis
Price drops to a low of $64/oz 1995
Telecom/datacom and mobile phone SAW fiter demand 2000
Mobile phone penetration picks up 2004
Smartphone revolution begins 2006
Notebook backlighting 2005
High LED demand and strategic Chinese investment 2010
Surge in demand due to expansion of LED technology 2010-11
Continued electrode demand growth for chloralkali process 2016
Capacity build for lithium tantalate for SAW filters in Japan 2016
Strong Chinese industrial buying 2015
Iridium bars become available 2016
Source: SFA (Oxford)

APPENDIX

Platinum supply-demand balance

koz	2009	2010	2011	2012	2013	2014	2015	2016	2017f
Primary supply									
Regional									
South Africa	4,550	4,725	4,595	4,200	4,355	3,115	4,465	4,245	4,200
Russia	775	790	800	780	740	740	715	715	735
Zimbabwe	230	280	340	365	405	405	405	490	440
North America	275	200	375	345	355	400	385	395	405
Other	0	120	145	180	215	220	180	180	180
Total	**5,830**	**6,115**	**6,255**	**5,870**	**6,070**	**4,880**	**6,150**	**6,025**	**5,960**
Demand & recycling									
Autocatalyst									
Gross demand	2,520	2,880	3,125	3,180	3,180	3,305	3,390	3,435	3,405
Recycling	835	955	1,210	1,175	1,120	1,255	1,190	1,235	1,255
Net demand	1,685	1,925	1,915	2,005	2,060	2,050	2,200	2,200	2,150
Jewellery									
Gross demand	2,680	2,170	2,450	2,760	2,945	3,000	2,880	2,565	2,530
Recycling	415	475	630	840	855	775	515	625	500
Net demand	2,265	1,695	1,820	1,920	2,090	2,225	2,365	1,940	2,030
Industrial demand	1,235	1,640	1,850	1,530	1,530	1,545	1,670	1,775	1,610
Other recycling	15	10	10	5	5	5	5	5	5
Gross demand	6,435	6,690	7,425	7,470	7,655	7,850	7,940	7,775	7,545
Recycling	1,265	1,440	1,850	2,020	1,980	2,035	1,710	1,865	1,760
Net demand	**5,170**	**5,250**	**5,575**	**5,450**	**5,675**	**5,815**	**6,230**	**5,910**	**5,785**
Market balance									
Balance (before ETFs)	660	865	680	420	395	-935	-80	115	175
ETFs (stock allocation)	385	575	175	200	905	215	-240	-10	
Balance after ETFs	**275**	**290**	**505**	**220**	**-510**	**-1,150**	**160**	**125**	

Source: SFA (Oxford)

Platinum demand and recycling summary

koz	2009	2010	2011	2012	2013	2014	2015	2016	2017f
Gross demand									
Autocatalyst									
North America	335	370	385	425	425	465	475	430	440
Western Europe	1,290	1,315	1,500	1,350	1,360	1,450	1,555	1,645	1,515
Japan	315	480	500	600	580	590	525	485	460
China	95	135	120	115	130	125	130	170	235
India	100	145	180	200	160	160	175	165	180
RoW	385	435	440	490	525	515	530	540	575
Total	**2,520**	**2,880**	**3,125**	**3,180**	**3,180**	**3,305**	**3,390**	**3,435**	**3,405**
Jewellery									
North America	140	160	160	185	200	230	250	265	275
Western Europe	185	180	175	175	220	220	235	240	250
Japan	430	370	315	325	335	335	340	335	320
China	1,860	1,370	1,670	1,915	1,990	1,975	1,765	1,410	1,330
India	40	50	80	105	140	175	220	245	280
RoW	25	40	50	55	60	65	70	70	75
Total	**2,680**	**2,170**	**2,450**	**2,760**	**2,945**	**3,000**	**2,880**	**2,565**	**2,530**
Industrial									
North America	210	265	265	320	325	320	260	390	345
Western Europe	275	285	275	250	170	225	305	265	250
Japan	130	150	205	90	90	30	90	95	25
China	125	390	310	380	520	450	545	580	500
RoW	495	550	795	490	425	520	470	445	490
Total	**1,235**	**1,640**	**1,850**	**1,530**	**1,530**	**1,545**	**1,670**	**1,775**	**1,610**
Total gross demand									
North America	685	795	810	930	950	1,015	985	1,085	1,060
Western Europe	1,750	1,780	1,950	1,775	1,750	1,895	2,095	2,150	2,015
Japan	875	1,000	1,020	1,015	1,005	955	955	915	805
China	2,080	1,895	2,100	2,410	2,640	2,550	2,440	2,160	2,065
RoW	1,045	1,220	1,545	1,340	1,310	1,435	1,465	1,465	1,600
Total	**6,435**	**6,690**	**7,425**	**7,470**	**7,655**	**7,850**	**7,940**	**7,775**	**7,545**
Recycling									
Autocatalyst									
North America	550	580	600	575	560	560	505	535	545
Western Europe	135	195	420	405	365	470	450	480	495
Japan	110	145	115	115	95	105	95	90	95
China	0	0	5	10	20	30	55	40	30
RoW	40	35	70	70	80	90	85	90	90
Total	**835**	**955**	**1,210**	**1,175**	**1,120**	**1,255**	**1,190**	**1,235**	**1,255**
Jewellery									
North America	0	0	0	0	0	0	5	5	5
Western Europe	0	0	0	0	0	5	5	5	5
Japan	130	150	285	285	250	235	160	150	155
China	285	325	345	555	600	530	340	460	330
RoW	0	0	0	0	5	5	5	5	5
Total	**415**	**475**	**630**	**840**	**855**	**775**	**515**	**625**	**500**
WEEE	**15**	**10**	**10**	**5**	**5**	**5**	**5**	**5**	**5**
Total recycling									
North America	555	580	600	575	560	565	515	540	550
Western Europe	135	200	425	405	365	475	455	485	500
Japan	245	295	400	400	345	340	255	240	250
China	285	325	355	570	620	560	395	500	360
RoW	45	40	70	70	90	95	90	100	100
Total	**1,265**	**1,440**	**1,850**	**2,020**	**1,980**	**2,035**	**1,710**	**1,865**	**1,760**

Source: SFA (Oxford)

Palladium supply-demand balance

koz	2009	2010	2011	2012	2013	2014	2015	2016	2017f
Primary supply									
Regional									
South Africa	2,425	2,590	2,550	2,355	2,360	1,855	2,560	2,360	2,350
Russia	2,675	2,720	2,705	2,630	2,580	2,690	2,605	2,555	2,700
Zimbabwe	180	225	265	280	315	330	325	395	330
North America	610	580	865	895	975	1,055	995	1,065	1,145
Other	0	300	390	445	450	460	455	425	405
Total	**5,890**	**6,415**	**6,775**	**6,605**	**6,680**	**6,390**	**6,940**	**6,800**	**6,930**
Demand & recycling									
Autocatalyst									
Gross demand	4,090	5,615	6,195	6,690	7,135	7,530	7,740	8,000	8,110
Recycling	1,155	1,395	1,525	1,485	1,645	1,720	1,630	1,755	1,790
Net demand	2,935	4,220	4,670	5,205	5,490	5,810	6,110	6,245	6,320
Jewellery									
Gross demand	775	695	680	545	350	295	240	240	215
Recycling	0	100	135	130	145	120	80	80	60
Net demand	775	595	545	415	205	175	160	160	155
Industrial demand	2,400	2,465	2,465	2,325	2,065	2,015	2,055	2,050	1,930
Other recycling	350	405	370	375	410	430	435	390	380
Gross demand	7,265	8,775	9,340	9,560	9,550	9,840	10,035	10,290	10,255
Recycling	1,505	1,900	2,030	1,990	2,200	2,270	2,145	2,225	2,230
Net demand	**5,760**	**6,875**	**7,310**	**7,570**	**7,350**	**7,570**	**7,890**	**8,065**	**8,025**
Market balance									
Balance (before ETFs)	130	-460	-535	-965	-670	-1,180	-950	-1,265	-1,095
ETFs (stock allocation)	505	1,085	-535	285	0	940	-670	-640	
Balance after ETFs	**-375**	**-1,545**	**0**	**-1,250**	**-670**	**-2,120**	**-280**	**-625**	

Source: SFA (Oxford)

Palladium demand and recycling summary

koz	2009	2010	2011	2012	2013	2014	2015	2016	2017f
Gross demand									
Autocatalyst									
North America	1,005	1,310	1,505	1,745	1,835	1,970	2,090	2,180	2,095
Western Europe	920	1,280	1,500	1,425	1,530	1,650	1,705	1,585	1,600
Japan	600	810	670	735	745	745	750	785	800
China	705	1,010	1,130	1,300	1,515	1,665	1,735	1,995	2,070
India	105	150	160	155	165	165	180	220	240
RoW	755	1,055	1,230	1,330	1,345	1,335	1,280	1,235	1,305
Total	**4,090**	**5,615**	**6,195**	**6,690**	**7,135**	**7,530**	**7,740**	**8,000**	**8,110**
Jewellery									
North America	60	65	45	45	40	35	35	35	35
Western Europe	50	65	65	80	75	60	55	55	55
Japan	80	85	90	95	65	55	50	50	50
China	560	450	450	295	145	120	75	75	50
RoW	25	30	30	30	25	25	25	25	25
Total	**775**	**695**	**680**	**545**	**350**	**295**	**240**	**240**	**215**
Industrial									
North America	495	500	495	480	405	400	410	410	380
Western Europe	365	410	375	335	305	300	305	300	280
Japan	595	575	550	565	420	430	440	430	400
China	420	435	425	405	455	425	435	440	415
RoW	525	545	620	540	480	460	465	470	455
Total	**2,400**	**2,465**	**2,465**	**2,325**	**2,065**	**2,015**	**2,055**	**2,050**	**1,930**
Total gross demand									
North America	1,560	1,875	2,045	2,270	2,280	2,405	2,535	2,625	2,510
Western Europe	1,335	1,755	1,940	1,840	1,910	2,010	2,065	1,940	1,935
Japan	1,275	1,470	1,310	1,395	1,230	1,230	1,240	1,265	1,250
China	1,685	1,895	2,005	2,000	2,115	2,210	2,245	2,510	2,535
RoW	1,410	1,780	2,040	2,055	2,015	1,985	1,950	1,950	2,025
Total	**7,265**	**8,775**	**9,340**	**9,560**	**9,550**	**9,840**	**10,035**	**10,290**	**10,255**
Recycling									
Autocatalyst									
North America	890	975	975	930	1,005	975	895	960	970
Western Europe	135	205	335	325	345	365	325	315	335
Japan	100	175	130	125	125	135	125	125	140
China	0	0	15	20	50	60	115	160	135
RoW	30	40	70	85	120	185	170	195	210
Total	**1,155**	**1,395**	**1,525**	**1,485**	**1,645**	**1,720**	**1,630**	**1,755**	**1,790**
Jewellery									
Japan	0	10	15	20	20	20	20	20	20
China	0	90	120	110	125	100	60	60	40
Total	**0**	**100**	**135**	**130**	**145**	**120**	**80**	**80**	**60**
WEEE									
North America	85	80	70	75	75	70	85	65	65
Western Europe	75	115	80	85	90	95	80	75	75
Japan	115	130	135	120	135	145	165	135	120
China	25	25	20	30	40	30	25	35	40
RoW	50	55	65	65	70	90	80	80	80
Total	**350**	**405**	**370**	**375**	**410**	**430**	**435**	**390**	**380**
Total recycling									
North America	975	1,055	1,045	1,005	1,080	1,045	980	1,025	1,035
Western Europe	210	320	415	410	435	460	405	390	410
Japan	215	315	280	265	280	300	310	280	280
China	25	115	155	160	215	190	200	255	215
RoW	80	95	135	150	190	275	250	275	290
Total	**1,505**	**1,900**	**2,030**	**1,990**	**2,200**	**2,270**	**2,145**	**2,225**	**2,230**

Source: SFA (Oxford)

Rhodium supply-demand balance

koz	2009	2010	2011	2012	2013	2014	2015	2016	2017f
Primary supply									
Regional									
South Africa	660	650	645	600	590	425	620	615	585
Russia	75	75	75	75	70	75	70	70	75
Zimbabwe	20	25	30	30	35	35	35	45	35
North America	20	15	30	30	35	30	30	25	25
Other	0	10	10	10	10	10	10	10	15
Total	**775**	**775**	**790**	**745**	**740**	**575**	**765**	**765**	**735**
Demand & recycling									
Autocatalyst									
Gross demand	585	730	740	770	785	835	860	835	830
Recycling	170	220	235	235	260	275	270	285	295
Net demand	415	510	505	535	525	560	590	550	535
Industrial demand	105	175	170	150	150	175	170	185	165
Other recycling	3	1	1	1	1	2	2	2	2
Gross demand	690	905	910	920	935	1,010	1,030	1,020	995
Recycling	175	220	235	235	260	275	270	285	295
Net demand	**515**	**685**	**675**	**685**	**675**	**735**	**760**	**735**	**700**
Market balance									
Balance (before ETFs)	260	90	115	60	65	-160	5	30	35
ETFs (stock allocation)			15	35	50	5	-5	5	
Balance after ETFs			**100**	**25**	**15**	**-165**	**10**	**25**	

Source: SFA (Oxford)

Rhodium demand and recycling summary

koz	2009	2010	2011	2012	2013	2014	2015	2016	2017f
Gross demand									
Autocatalyst									
North America	150	180	180	200	220	235	255	255	245
Western Europe	190	200	215	190	195	220	235	195	190
Japan	115	165	135	150	140	140	125	125	125
China	45	70	75	90	95	105	110	130	135
India	10	15	20	20	15	15	15	20	20
RoW	75	100	115	120	120	120	120	110	115
Total	**585**	**730**	**740**	**770**	**785**	**835**	**860**	**835**	**830**
Industrial									
North America	10	15	20	15	15	15	15	20	15
Western Europe	15	25	20	20	10	15	15	15	15
Japan	35	45	45	45	35	30	35	30	30
China	20	40	40	30	45	55	50	60	50
RoW	25	50	45	40	45	60	55	60	55
Total	**105**	**175**	**170**	**150**	**150**	**175**	**170**	**185**	**165**
Total gross demand									
North America	160	195	200	215	235	250	270	275	260
Western Europe	205	225	235	210	205	235	250	210	205
Japan	150	210	180	195	175	170	160	155	155
China	65	110	115	120	140	160	160	190	185
RoW	110	165	180	180	180	195	190	190	190
Total	**690**	**905**	**910**	**920**	**935**	**1,010**	**1,030**	**1,020**	**995**
Recycling									
Autocatalyst									
North America	125	160	140	145	165	160	150	160	165
Western Europe	20	30	60	60	55	60	60	60	65
Japan	20	25	25	25	25	30	30	35	35
China	0	0	0	0	5	5	10	5	5
RoW	5	5	10	5	10	20	20	25	25
Total	**170**	**220**	**235**	**235**	**260**	**275**	**270**	**285**	**295**

Source: SFA (Oxford)

GLOSSARY OF TERMS

Basket price

Collective revenue of metals divided by 4E oz.

By-products

Copper, nickel, iridium and ruthenium.

ETF

Exchange-traded fund.

Gross demand

A measure of intensity of use.

HDV

Heavy-duty vehicle.

koz

A thousand troy ounces.

LCV

Light commercial vehicle.

Lease rates

Fees payable for the rental of an asset.

Merensky Reef

A PGM-bearing horizon within the Bushveld Igneous Complex, South Africa. Also contains nickel and copper sulphides that are mined as by-products.

MLCCs

Multi-layered ceramic capacitors.

Moody's

The bond credit rating business of Moody's Corporation.

moz

A million troy ounces.

Net demand

A measure of the theoretical requirement for new metal, i.e. net of recycling.

Net supply

Proxy supply of metal surplus to requirements.

NYMEX

New York Mercantile Exchange.

OLED

Organic light-emitting diode.

oz

Troy ounce.

Platreef

A PGM-bearing horizon mined on the Northern Limb of the Bushveld Igneous Complex. Characterised by a wide reef and base metal by-products.

PGMs

Platinum-group metals.

Price elastic

Susceptible to changes in price.

Primary supply

Mine production.

Producer sales

Mine output plus inventory sold to market.

SAW filters

Surface acoustic wave filters; increasingly ubiquitous electronic components found in wireless communications equipment, often use iridium crucibles to make lithium tantalate and lithium niobate for SAW filters.

Secondary supply

Recycling output.

S&P 500

Standard & Poor's 500 Index is an index of the largest 500 US companies by market capitalisation.

SUV

Sport utility vehicle.

TOCOM

Tokyo Commodity Exchange.

UG2 Reef

A PGM-bearing horizon within the Bushveld Igneous Complex, located stratigraphically below the Merensky Reef. One of the main chromite-bearing reefs of the Bushveld Igneous Complex. Typically comprises lower base metals contents than the Merensky Reef.

3G and 4G networks

Third and fourth generation mobile telecommunications technology networks.

4E

Platinum, palladium, rhodium and gold.

5E

Platinum, palladium, rhodium, ruthenium and iridium.

Currency symbols

ZAR	South African rand.
$	US dollar.

METHODOLOGY

Primary supply is calculated from actual mine production and excludes the sale of stock in order to provide pure production data. Stock sales are treated separately in SFA's database as movement of stocks. Therefore, state stock sales from Russia are excluded in tabulations.

Gross demand is a measure of intensity of use.

Net demand is a measure of the theoretical requirement for new metal, i.e. net of recycling.

Automotive demand is based on vehicle production data not sales.

ACKNOWLEDGEMENTS

SFA (Oxford) would like to thank all those whose hard work contributed to turning what began as an ambitious idea into the finished report you now see in front of you.

In particular, we would like to acknowledge our team:

Alex Biddle
Beresford Clarke
Dr. Jenny Watts
Dr. Ralph Grimble
Elaine Forrest
David Mobbs
Oksan Atilan
Samantha Trickey
Stephen Forrest
Tom Chandler
Tracy Lindsay
Jamie Underwood

We should also mention a team of Associate Consultants, without whom this publication would not have been possible.

A special mention should also be given to Jeremy Coombes and Andy Smith whose combined knowledge of and expertise in compiling such an ambitious PGM industry review helped to fashion a report of which we could all be thoroughly proud.

We thank Janice Hurst and Karen Darley for proofreading The Platinum Standard throughout its production.

Then there are our third-party data suppliers: LMC Automotive, Oxford Economics, Power Systems Research, and GTIS whose data form the basis of many of the charts in this report.

Finally, to our clients and all those who have supported us throughout our time in business, we would like to dedicate this report as a mark of our gratitude for your continuing support.

Designed and typeset by Jamie Underwood and Alex Biddle.

Printed by Holywell Press Ltd, Oxford.

NOTES

Please note: Some tabulated data may not add up owing to rounding of individual numbers.

© Published in May 2017 by SFA (Oxford) Ltd.

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