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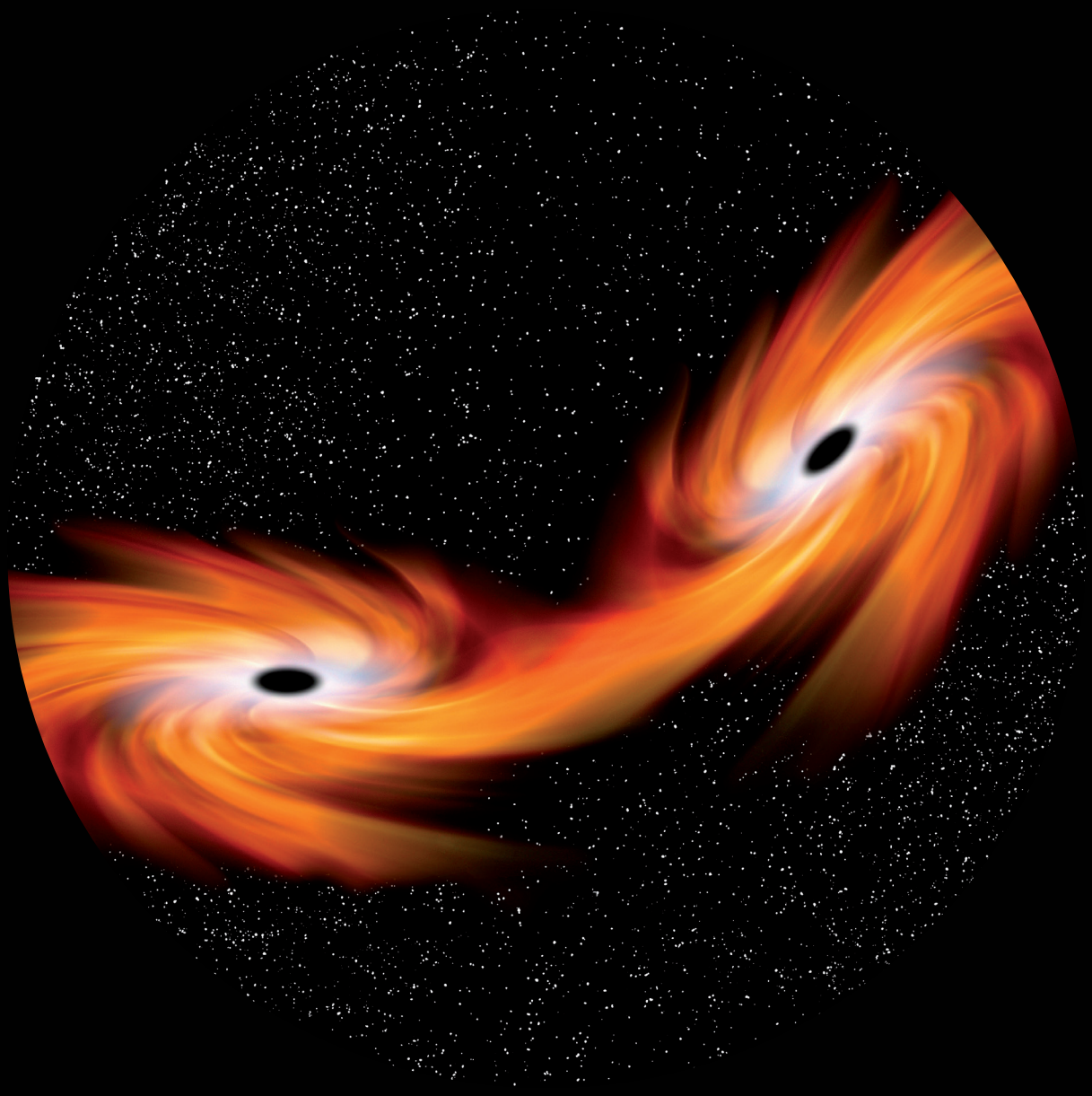

The chemical multiverse 4.0

Promising future for the strong, decisive, and persistent

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Executive summary

In the wake of the dramatic economic downturn of the second half of 2008 and throughout 2009, Deloitte Touche Tohmatsu Limited (Deloitte Global) launched the Chemicals 2020 trilogy. This series of reports titled *The decade ahead* (December 2009), *The chemical multiverse* (November 2010), and *The end market alchemy* (October 2011), was grounded in four areas:[1]

1. State of the chemical industry, as a whole
2. Position of individual companies that manufactured and sold chemicals and plastics
3. Habits and patterns of customers
4. Economic environment in major regions of the world

This next report in the series, entitled *The chemical multiverse 4.0,* seeks to accomplish much the same thing, albeit in a very different context. The times have changed and so has the chemical industry. Despite extraordinary pressures from a multitude of sources, the industry has continued to perform and mature. Additionally, it has adjusted its strategies as needed to manage feedstock volatility, handle slumps driven by key buyers in the automotive and construction industries, and manage the emergence of massive state-owned enterprises in China.

For some, these strategy resets led to greater focus on the core business and finding profit in efficiency and higher productivity. For others, it has meant seeking growth through acquisition, as well as becoming more customer focused.

While these changes have yielded many positive results so far, the industry cannot likely afford to rest on past laurels. Excess capacity, dormant cash, weak demand growth, declining trade, and continued uncertainty surrounding feedstock prices are just a few of the factors that make predicting the future for the industry a difficult assignment.

That said, a revolution may be brewing throughout the manufacturing world. Dubbed "Industry 4.0," it hopes to create the Digital Manufacturing Enterprise (DME) by popularizing digital tools that can upend the way companies develop products and interact with their customers and the rest of the industry.

Although late in arriving, chemical companies are now starting to embrace these tools to help them refine their businesses, accelerate product development, and understand their customers' current and future unmet needs.

How companies deal with these ongoing uncertainties and the potentialities of digital will depend to a great degree on their current situation. To that end, this report will share a refreshed comprehensive industry map to help companies understand their options—both financial and strategic—when it comes to meeting these challenges.

In addition to those challenges presented by Industry 4.0, chemical companies will also likely have to contend with ongoing macroeconomic trends. Among these are mixed messages from the automotive sector, where fewer drivers means fewer cars and therefore less demand for traditional chemicals and specialty materials. At the same time, however, new cars should be lighter and more fuel efficient, a trend that could create new opportunities for new chemicals and specialty materials. This is but one example of an industry-shaping trend executives need to prepare for and stand ready to manage. Another is the much-discussed talent crisis, a factor in many industries but particularly acute for chemicals, where new realities brought on by Industry 4.0 will require new skills from diverse workplaces.

Once armed with this knowledge, chemical companies can then decide what kind of company they want to be, heading towards 2025. All the major sectors including Natural Owners, Differentiated Commodity Makers, and Solutions Providers will be viable, but not all companies will find themselves competing in the same space in the future.

It is a fascinating time to be in the chemical industry. With that in mind, this report is aptly titled *The chemical multiverse 4.0*. The changes taking place are truly remarkable and the challenges ahead are equally daunting. Never before has it been so important for companies to understand where they stand now and where they plan to be in the future. *The chemical multiverse 4.0* was designed to serve as a vital aid to help get companies there and support their business goals.

Introduction

The years following the great recession were extraordinarily volatile for hydrocarbons. Oil prices plummeted from US$136 per barrel in 2008 to US$41 per barrel in 2009.[2] While shale gas investment was certainly underway in 2008, its impact on the chemical industry was not fully understood until later. This was also a time when the gross domestic products (GDPs) of Brazil, Russia, India, and China (the BRIC countries) countries were, by and large, posting impressive growth. And yet, the impact of great recession eclipsed all of these positive forces.

During those years, it was unclear if chemical companies needed to wait for an economic rebound, as in most previous down cycles, or if the time had come to restart. In retrospect, what occurred was more of an economic reset than a rebound. Two important sectors for chemicals, including automotive and construction, have only now begun to approach their pre-recession volumes. *The chemical multiverse 4.0* will explore various macroeconomic forces, as well as their effect on end-user industries in the following sections.

Since launching the Chemicals 2020 series, Deloitte Development LLC has developed and repeatedly refreshed a database that has ranged from 220 and 250 firms (depending on the number of public chemical companies each year) and tracked other meaningful chemical industry data in order to refresh the basic analysis. Over time, the refreshes have revealed interesting trends and unique patterns in the industry. The subsequent evaluations helped us to develop a better understanding of the industry through analytics, which in turn, helped numerous chemical companies compare their strengths and deficiencies to those of their competitors. The analytics launched in the Chemicals 2020 series also provided insights into the evolving nature of customers and suppliers. Lastly, by looking at companies in the industry on a series of value maps over time, the analytics helped contextualize the increasing and unprecedented levels of portfolio changes, especially since 2014.

What was learned from updating the Chemicals 2020 series was undoubtedly useful, but in a traditional, largely incremental way. Yearly refreshes may no longer be sufficient to explain the different dynamics and challenges occurring in the chemical industry. More research and thought is likely required to contend with the new and innovative ways companies have responded to the most recent cycle.

Exponential and digital technologies have evolved beyond experimentation into a landscape-changing driver. These days, companies are naturally very curious about the potential value of these technologies as the DME continues to develop. Companies are likely also mindful of the technologies' disruptive nature. This is an entirely new landscape and, as such, supports the notion that the time is right to dig deeper into what lies ahead and understand what the chemical industry will become. It is likely necessary to extend the time horizon from the Chemicals 2020 series to at least 2025 or 2030. Moreover, we are compelled to ask again, as in 2009, if the chemical industry is staring at another reset button. *The chemical multiverse 4.0* is a first major step towards helping to answer that question.

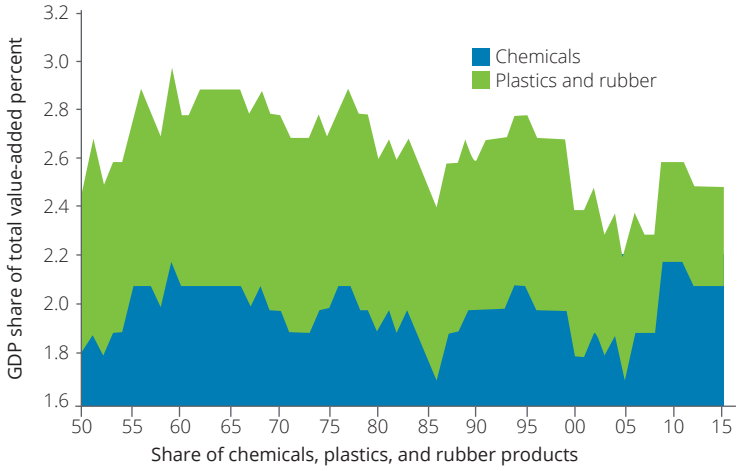
Why chemicals matter, now more than ever

US Government statisticians provide information about two related industries: Chemical manufacturing (NAICS 325) and Plastics and Rubber Products Manufacturing (NAICS 326).[3] Together these industries accounted for 2.5 percent of US GDP by value-added percent in 2015 (See Figure 1). While on its own this may seem an insignificant figure, the overall effect of chemical manufacturing actually contributes to nearly 26 percent of US GDP, according to the American Chemistry Council.[4]

The share of chemicals and plastics in GDP has been relatively constant, yet the combined industry's share of total employment dropped from 1.7 percent in 1990 to 1.3 percent in 2015, or from 1.9 million jobs in 1990 to 1.5 million in 2015 (See Figure 2). Nevertheless, the chemical industry has a large multiplier effect. For example, one new job in chemical manufacturing creates another eight jobs across the entire US economy.[5]

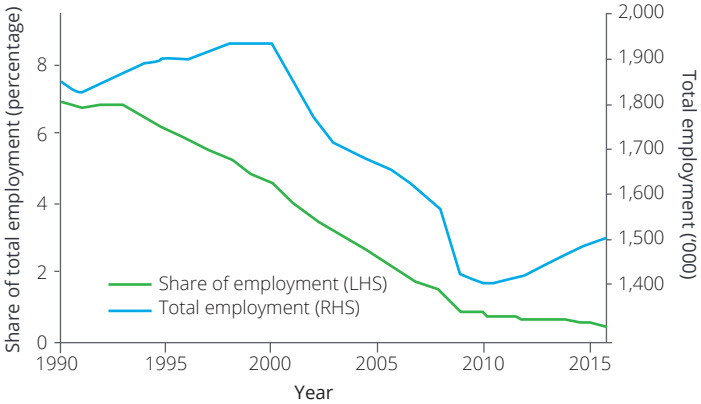
The chemical industry is also an important contributor to other industries. About 48 percent of the industry's output was used in other sectors, mainly other manufacturing industries.[6] Meanwhile, 38 percent went to private consumption (mainly sold through retailers) and 12 percent was exported.[7]

Figure 1: Share of chemicals, plastics, and rubber products in GDP share of total value-added percent



Source: Deloitte Development LLC analysis of data from US Bureau of Economic Analysis and Haver Analytics, accessed in May 2017.

Figure 2: Total employment and share of total employment in chemicals, plastics, and rubber industries



Source: Deloitte Development LLC analysis of data from US Bureau of Economic Analysis and Haver Analytics, accessed in May 2017.

Optimism in the face of uncertainty

Upbeat manufacturing activity is a positive sign

Growth in the global economy has slowed down in recent years. Generally speaking, business investment is weak, cross-border trade in goods and services is dwindling, and physical goods are under persistent deflationary pressures. More specifically, the US economy is growing at a steady rate of around 2 percent annually and over the next two years, a strengthening labor market and increased real household income should fuel consumer spending and keep the American economy growing.[8] Meanwhile, China's economy has been sluggish and subject to uncertainty. With excessive levels of debt in China and the government shifting its focus from infrastructure investment to domestic consumption, the economy will likely continue to grow at a slower pace through 2018.[9] While fears of the impact of Brexit have calmed, the outlook for growth in Europe remains unpromising, as demand is weak and monetary policy changes have yet to create the desired impact.

Despite slowing growth in key geographies, projections call for broad improvement in manufacturing activity. Indeed, manufacturing across major chemical-producing regions has gained momentum over the past two years and is poised to continue on the same trajectory in the near future. In the US, for example, activity is buoyant with growth in new orders, industrial production, and employment.[10] Manufacturing in Europe is also showing improved performance as indicated by the purchasing managers' index (PMI) data, which points towards expansion.[11] While activity in China remains slower when compared with 2010, manufacturing is still expanding modestly with both production and demand appearing to be stabilizing.[12]

However, this cautiously optimistic picture hides a long-term reality. Manufacturing is poised for disruption, especially in the face of advances in exponential technologies such as nano-sciences, robotics, artificial intelligence and machine learning, autonomous transportation, and additive manufacturing. There is also a distinct possibility that shared consumption models will affect manufacturing in the same way, as they are on the verge of disrupting the hospitality industry, automobile ownership, and contract labor and services. Examples of crowdsourcing and crowd-funding trends are already showing signs of catching on in manufacturing, as companies seek to differentiate themselves in new ecosystems and pursue open innovation.

As our analysis will reveal, many chemical companies are well positioned to realize the benefits of this optimistic outlook. However, nearly all companies are challenged to develop capabilities and employ resources beyond their core businesses.

Global chemical trade to decline further as China closes the export-import gap

Like the overall trade in goods and services, global trade in chemicals and related products has slowed since 2011 and even declined in 2015.[13] Trade in chemicals differs from one region to another, based on competitiveness of the local supply chain, raw material advantage, and capacity to process value-added products.

One indicator of these differing regional pictures is the variability between regions in terms of exports over the last 10 years. Chemical exports from regions like China and the Middle East grew at double-digit rates (greater than 12 percent), while exports from Europe and United States grew at less than 5 percent annually (see Figure 3). China is expected to continue growing its manufacturing base and adding more value-added chemicals and plastics to its production mix. While China will certainly persist as a manufacturing behemoth, it remains to be seen whether it will continue to register double-digit export growth of chemicals and plastics in the next decade.

China, however, is complex. It continues to be a net importer of chemicals in terms of value, but in terms of volume, it has already become a net exporter of many key chemicals and materials.[14] This indicates that the country is slowly closing the export-import gap in chemicals.[15] The Middle East is also doing particularly well as a net exporter after SABIC acquired DSM's petrochemicals business in 2002.[16] Net chemical exports from Europe have been in decline, but at a slackening pace, as evidenced by the marginal decrease in 2015. Exports from the US have declined as well. In all likelihood, this is because of the strength of the US$ but the decline may also be due to higher levels of imports.[17] Despite challenging conditions, the American Chemistry Council forecasts that US net chemical

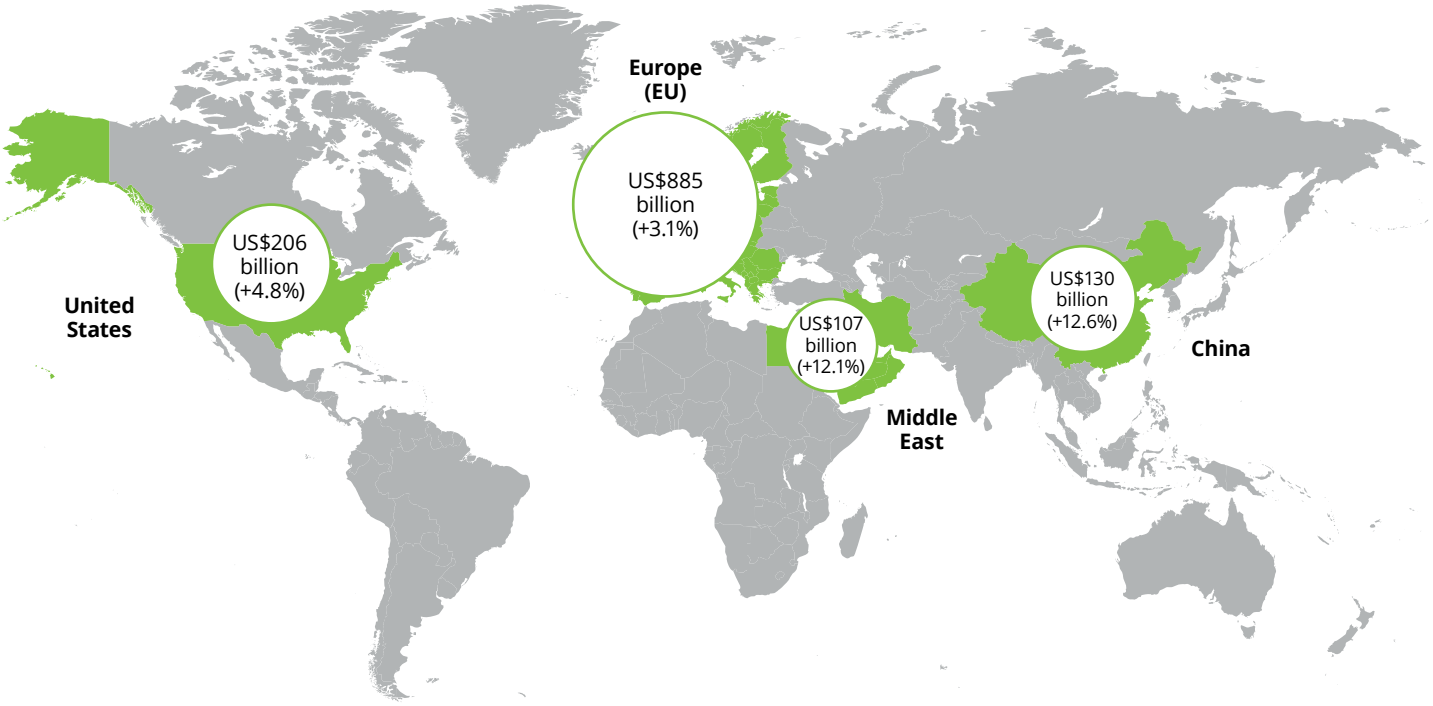
exports will improve. Its projection is based on the completion of new investments and improved performance of the economies of its trading partners.[18]

Another indicator of reduced trade in chemicals is the decline in freight prices. This is likely due, in part, to subdued demand for manufactured goods and products transported over long distances, which in turn leads to less trade for manufactured goods, as well as chemicals.[19] Overcapacity in the global shipping industry applies equally to those companies shipping chemicals and is expected to be a challenge moving forward.[20] Perhaps a surge in trade of chemicals (an unlikely scenario) is one of the only ways to correct the current imbalance and improve the situation.

Recent capital investments to increase capacity (mainly to production, but also storage and transportation) have largely been used to meet local, rather than global, chemical demand.

Moreover, as capital spending has steadily declined (as a percentage of earnings before interest, tax, depreciation, and amortization (EBITDA)) since 2001, it is difficult to count on the historic, predictable cycles of supply and demand. While continued discipline and caution with capital deployment may help close the gap between supply and demand, overcapacities currently exist in widely traded commodities such as polyethylene, poly vinyl chloride, and acrylic acid.[21] As such, on one hand, exports from regions with excess capacity may grow (after meeting local demand), on the other hand, regionalization of capacity and regional self-sufficiency may mean even greater declines in the global chemical trade. Only dramatically higher oil prices can turn the tables for the chemical industry and may also be a primary cause of growth in worldwide exports, as countries with low-cost hydrocarbons exploit this advantage.

Figure 3: Chemical exports (2015) and annual export growth rate (compound annual growth rate from 2006 to 2015)

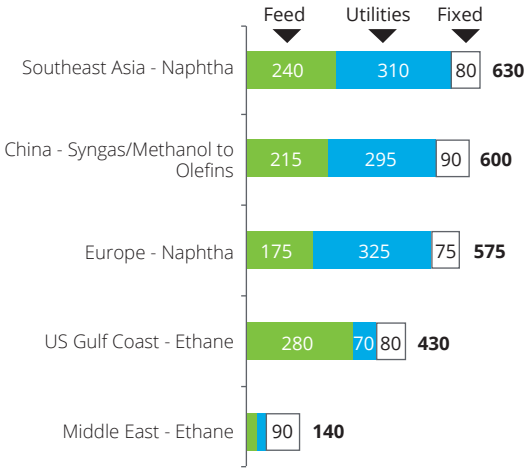


Note: The US, Europe, China, and the Middle East represent over 70 percent of total global exports in chemicals and specialty materials.
Source: Deloitte Development LLC analysis of data from United Nations Trade and Development, accessed in May 2017.

Changing commodities environment amid demand uncertainty

Weakening demand growth, changing production controls by the Organization of the Petroleum Exporting Countries (OPEC), and a resurgence in drilling activity in the US (especially shale) have all contributed to historical weakness in oil prices globally.[22] This plunge was a cause for celebration for the petrochemical companies in Europe and Asia, as lower cost hydrocarbons enabled better profit margins and the ability to operate some plants more efficiently. However, for the Middle East and US producers the story was different. These companies witnessed their profits shrink, as the margin gap narrowed between ethane (produced from natural gas in the US and Middle East) and naphtha (produced from crude oil in Europe and Asia).[23] Western European companies are only cost competitive in the low-probability case of sub US$30/barrel of oil (see Figure 4).

Figure 4: Ethylene cash cost evolution



Note: Units are US$/metric ton.
Source: Deloitte Development LLC analysis of data from Deutsche Bank, *Chemicals for Beginner, The industry guide: 6th edition*, May 15, 2015.

Interview with an industry executive: The impact of economic scenarios

To test our scenarios, a chemical industry executive, leader of both specialty and semi-commodity businesses at a global top 50 chemical companies, was interviewed. His unique perspective on the impact of differing economic scenarios was shaped by the positions he held in two different chemical entities, including one pre-recession and the other post-recession. This executive led a sector leading specialty business from 2003 to 2007 and a global leading semi-commodity business from 2007 to 2016.

Based on your personal experiences in various chemicals businesses, what are your thoughts on the economic scenarios that may play out?

I see two different economic scenarios. On one hand, we had the post dot.com bubble (2003 to 2007), when input prices for chemical companies were volatile, including the price of oil, which reached its high of US$146 in July 2008. On the other hand, we had the post great recession (2010 to 2015), which was a period of deflation characterized by more stable input prices. This was first due to the collapse in global demand and then later the advance of non-traditional oil and natural gas recovery technologies.

Are periods of inflation necessarily better for chemical businesses, versus periods of deflation?

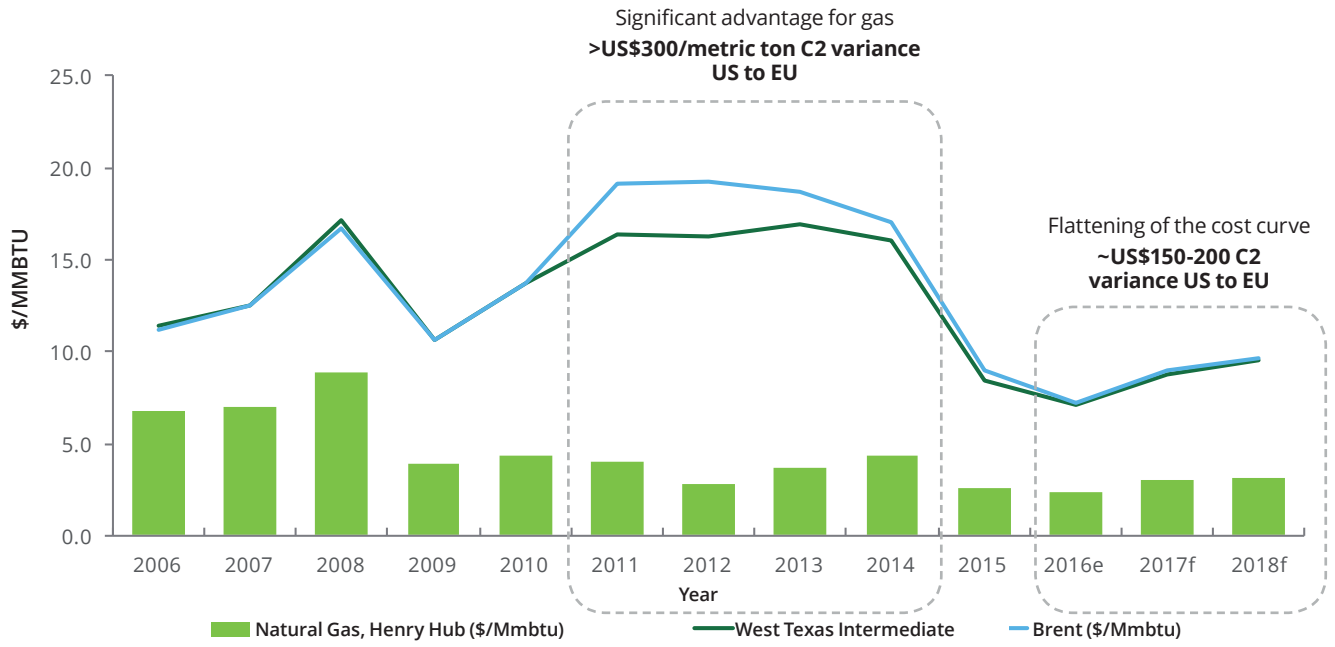
I agree that periods of inflation are better than periods of deflation, since chemical businesses tend to register higher profits during periods of inflation. There are, however, two additional aspects that should be considered.

The first includes the impact of investments in China between 2003 and 2015 that continue to this day. The investments in plant and equipment in China have been driven primarily by the strategic imperative of the Chinese government. This helps to establish enough domestic chemical production capacity to become independent of imports. Additionally, the Chinese investments have been a continuous source of on-and-off supply-demand imbalances in specific chemical product groups. These supply-demand shifts tend to overwhelm other macro-economic trends in a specific chemicals sector.

The second aspect includes periods of raw material (or input) inflation, versus deflation. This will likely play out differently in specialty and commodity chemicals and materials. Because specialty products already generally enjoy a higher margin, there is more resistance from customers to price increases based on "headlines" of input inflation. Commodity chemicals, on the other hand, barring a significant oversupply situation, are likely able to pass on the inflationary expectations of input price increases.

Source: Deloitte Development LLC, May 2017.

Figure 5: Crude oil and natural gas prices (2006 to 2018)



Note: (Mmbtu) is millions of British thermal units.
Source: Deloitte Canada, *Resource Evaluation & Advisory, Price Forecast*, September 2016, www.deloitte.ca/priceforecast.

The market is also dealing with excess supply of certain commodities as a result of new capacity. New natural-gas-based assets on the US Gulf Coast and in the Middle East have steadily come on stream with a net addition of 9 percent to global C2 capacity by 2018 (see Figure 6). A world-scale cracker facility is already under construction in India and, with expected increases to the number of coal-based assets in China, the petrochemical supply will further increase. Without corresponding reductions in capacity elsewhere and in a potential market of stabilizing oil prices, it is expected that there will be some form of a price correction, with ethylene prices as the baseline. Furthermore, China's increasing self-sufficiency in polypropylene and the threat to closing the gap in C2 chemicals could place increased strain on new assets in the US and the Middle East. This will likely trigger a need to increase exports.

Asset utilization and pricing should continue to be influenced by the cost competitiveness of natural gas, versus crude oil. While there may be unique trends in the markets that could provide some degree of protection for certain products, such as the C4 chemicals or the downstream C3 chemicals, the broader outlook for most commodities is to be oversupplied with limited options for export.

Figure 6: Ethylene capacity increases expected through 2018

	Region	Size (kt)	As a percentage of 2014 global capacity	Feedstock
2015				
	Mexico	250	0.2%	Ethane
	India	550	0.4%	EPB/Ethane
	UAE	750	0.5%	Ethane
	China	400	0.3%	Coal to olefins
	China	275	0.2%	Recovery from FCC/DCC Unit, Coal to olefins
2016				
	Mexico	800	0.5%	Ethane
	India	550	0.4%	EPB/Ethane
	Iran	500	0.3%	Ethane
	China	450	0.3%	Coal to olefins
2017				
	US	600	0.4%	Ethane
	Iran	500	0.3%	Ethane
	India	1,350	0.9%	EPB/Naphtha
2018				
	US	1,550	1.0%	Ethane
	China	1,000	0.6%	Naphtha/Gas oil/Residues

Source: Deloitte Development LLC analysis of data from Deutsche Bank, accessed in May 2017.

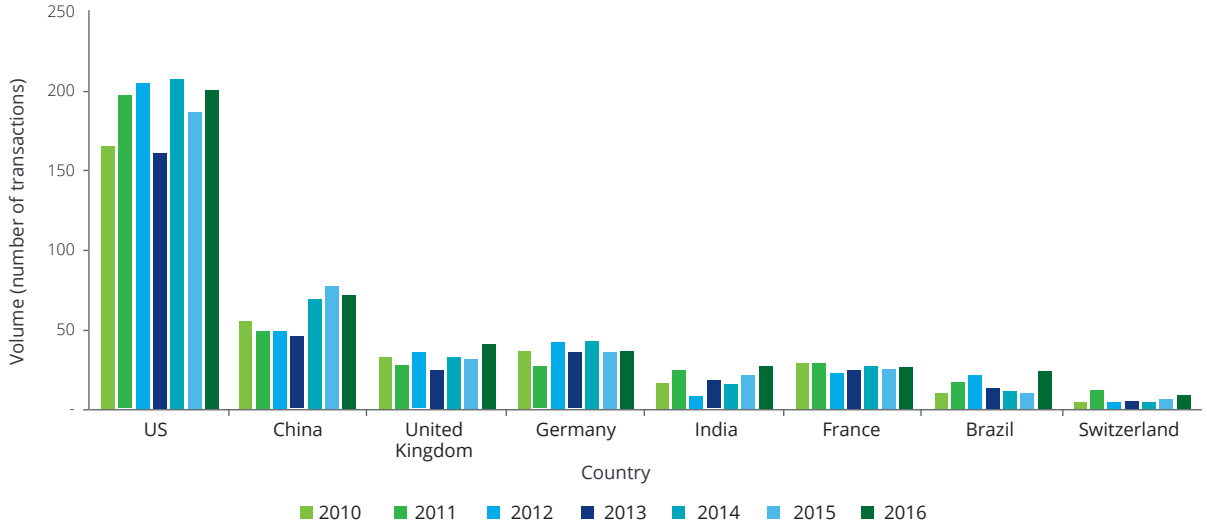
The response of chemical companies to the uncertain market varies. Some have reduced their product portfolio to a specific set of chemicals (in the short term). Others are betting that differentiation in the solutions space and broadening the portfolio is the winning strategy. While such strategic choices about portfolios depend on many factors, such as product line cyclicality, commodity exposure, regional dynamics, and feedstock sourcing, there is no one-size-fits-all approach. That said, standing still (neither narrowing nor broadening) is perhaps the likely highest-risk strategy in today's environment.

Sector consolidation to continue, especially in the specialty chemicals and materials segment

Transactions in the chemicals sector have marched steadily forward since 2013. In 2016 alone, US$231.1 billion worth of global mergers and/or acquisitions (M&A) activity were announced.[24] This is a significant increase compared over with the US$145.8 billion worth of deals in 2015.[25] While most of this M&A activity is concentrated on targets in the US (see Figure 7), acquirers from Europe and China are becoming more active in large, multi-billion dollar deals.

Of particular note are the M&A deals totaling US$70 billion from Germany alone.[26] German chemical conglomerates are looking to consolidate their current key positions, as well as diversify their product portfolios. China is not far behind. Many Chinese chemical companies are growing by buying assets and companies in other countries, including ChemChina's acquisition of Syngenta AG for US$43 billion.[27]

Figure 7: Chemical mergers and acquisitions activity in key geographies (2010 to 2016)



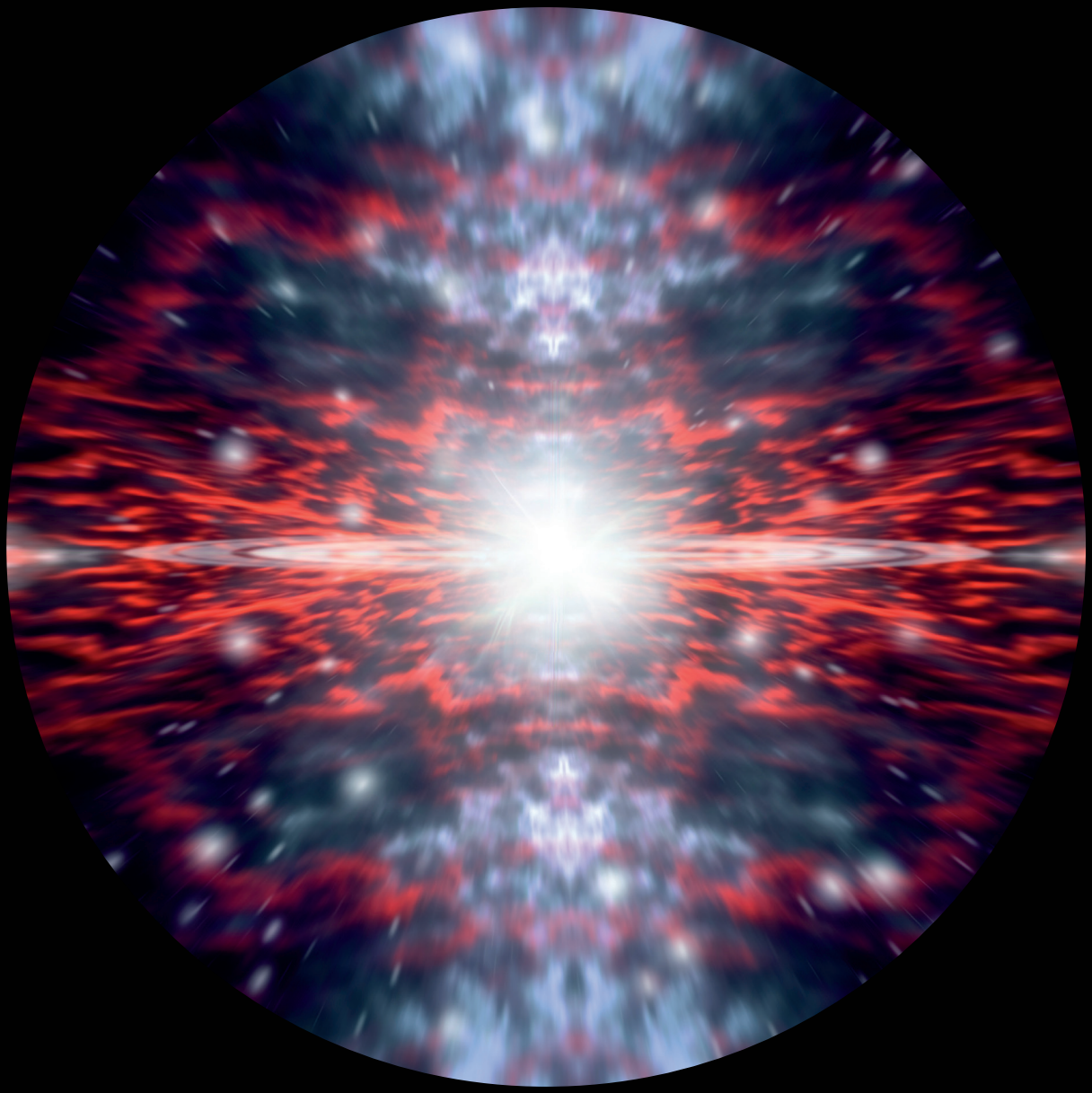
Total activity—by target market (2010 to 2016)

	2010	2011	2012	2013	2014	2015	2016
United States (US)	165	197	204	160	206	186	201
China	57	50	50	48	70	78	72
United Kingdom (UK)	35	29	37	27	35	33	41
Germany	37	28	44	37	44	37	38
India	17	27	10	20	17	23	28
France	30	29	24	26	28	25	26
Brazil	12	18	23	15	12	10	24
Switzerland	6	13	5	6	5	7	9
Other	220	255	212	198	218	213	211
Total	**579**	**646**	**609**	**537**	**635**	**612**	**650**

Source: Deloitte Development LLC analysis of data from S&P Capital IQ, January 2017. Data is from January 1, 2010, to December 31, 2016.

While portfolio changes (including divestitures, mergers, acquisitions, and spinoffs) are taking place in all chemical segments, some are experiencing more activity than usual. Agrochemicals saw three mega deals announced. This consolidation is, in part, the response to a drop in commodity prices and its pressure on farm incomes. It is also likely due to the growing convergence between the seed and pesticide markets. The acquisition of Syngenta AG, a Swiss chemical and seeds company, by ChemChina; and the acquisition of Monsanto by Bayer, confirms the trend.[28] It also shows that companies are focused on the convergence of research and development (R&D) efforts between plant genetics and crop protection, as well as the benefits of R&D when the two are linked.

The year 2016 was also a strong one for M&As in the commodities chemicals segment. It remained the most active sector in terms of deal volume. Portfolio shuffling is likely to continue with future transactions focused on intermediates and specialty chemicals, other fragmented segments, and even smaller scale commodities now that multiples have stabilized. Global adhesives and sealants are especially strong candidates for consolidation as close to 60 percent of the segment is comprised of several small- and medium-sized companies.[29]



Well along the curve: Lessons since 2008

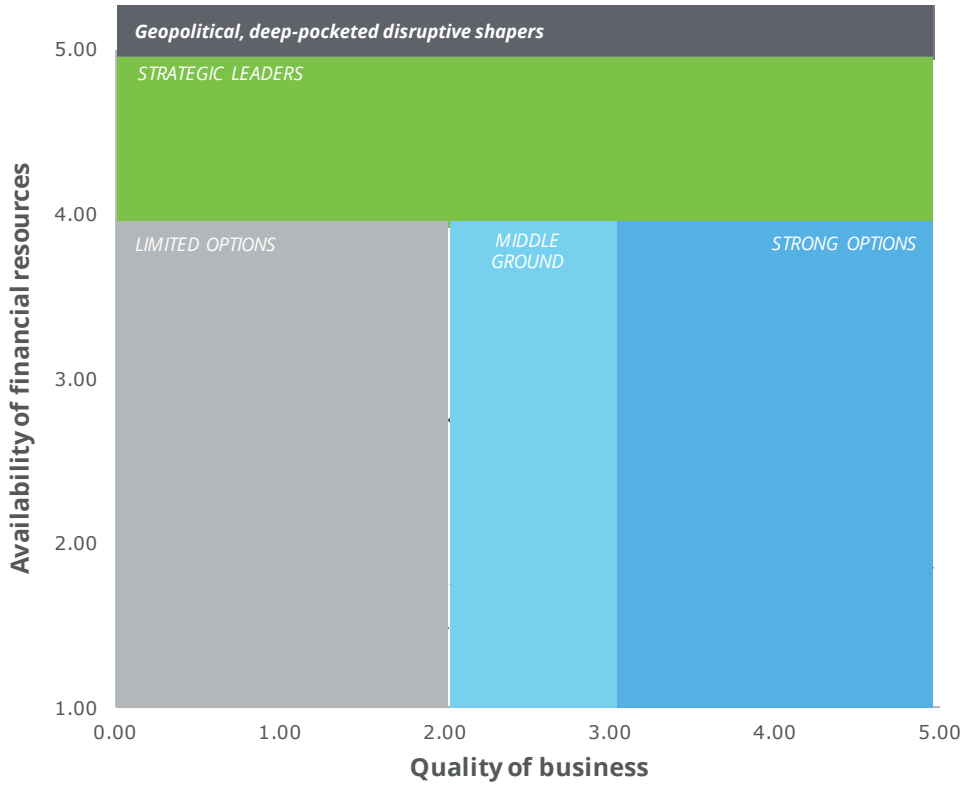
In 2008, global chemical industry revenues exceeded US$3 trillion and and it was speculated that the industry would top US$4 trillion by 2020.[30] Today, global chemical revenues have already reached US$4 trillion and now the question is how long it will be before revenues top US$5 trillion and what conditions the industry will face as it marches towards that milestone.[31]

In late 2010, The chemical multiverse plotted 228 publicly traded companies with annual sales of more than US$1 billion. The aim was to create a more meaningful segmentation/classification for the industry (see Figure 8).[32] Mapping availability of financial resources against quality of business put the companies into their natural territories and helped define initial positions. This helped define the "new normal."

Figure 8 shows five basic regions:

1. Geopolitical, deep-pocketed disruptive shapers
2. Strategic Leaders
3. Strong Options
4. Middle Ground
5. Limited Options

Figure 8: New categorizations



Source: Deloitte Development LLC analysis of data from Capital IQ, May 2017.

A different look at the chemical industry

Conventional approaches towards segmenting the chemical industry into commodity, integrated, and specialty chemicals categories are inadequate and do not fully explain financial performance. This is mainly because most chemical companies are not in pure-play chemical segments but rather have diversified into multiple categories.

This new initial segmentation approach was identified in November 2010 during the development of *The chemical multiverse*. Continuing past efforts, the same approach was adopted to make sense of individual companies' financial results. Availability of financial resources' was plotted against 'Quality of businesses.' While the former captures static resources that can only be spent one time (like cash, debt-paying capacity, or pre-paid assets) the latter measures company performance using these financial resources based on metrics like return on assets (ROA), return on capital (ROC), return on equity (ROE), and profit (EBITDA) growth. Plotting a chemical company on this two dimensional plane can reveal the essential 'starting point' and help the company decide its future course of action.

The weighted score of 'Availability of financial resources' comprises the following metrics:

- Cash and securities (2015): Cash and marketable securities based on balance sheet as of December 31, 2015
- Operating cash flow (2015)
- Interest coverage ratio (2013 to 2015): EBIT/interest expense
- Earnings before interest and taxes (EBIT)/Maintenance capital (2015): Maintenance capital proxy as defined by depreciation and amortization
- Enterprise value (2015)

The weighted score of 'Quality of business' comprises the following metrics:

- R&D expenditure as a percent of revenues (1998 to 2015)
- ROA (1998 to 2015): Net income/Total assets
- ROC (1998 to 2015): EBIT/Total capital (Net fixed assets + Net working capital)
- EBITDA growth (2012 to 2015)
- ROE (1998 to 2015) - Net income/Shareholders' equity

Scoring for each of these metrics is based on thresholds, using appropriate statistical methods. In cases where there was significant correlation, a linear line fit was used to calculate scores. In cases where the correlation was weak, thresholds were set based on a normal curve fit, using a step function scoring system.

Source: Deloitte Development LLC, May 2017.

Updating the map annually has helped visualize the changes in the industry using what is called the 'starting point analysis.' By looking at the individual financial metrics, each company has its own story, which inspired the title The chemical multiverse (November 2010), and reflects the uniqueness of each company. It is a title that is still appropriate for this report.

"Multiverse" refers to a "hypothetical set of finite and infinite possible universes, including the universe in which we live."[33] The analysis described in the next section reveals that every chemical company behaves uniquely. Moreover, just as asteroids and comets can cause chaotic events in a given universe, large macroeconomic forces tend to disrupt the way forward for chemical companies. Some of these varied forces are described in the previous section. Later, the report will assess each region and analyze patterns that will likely emerge.

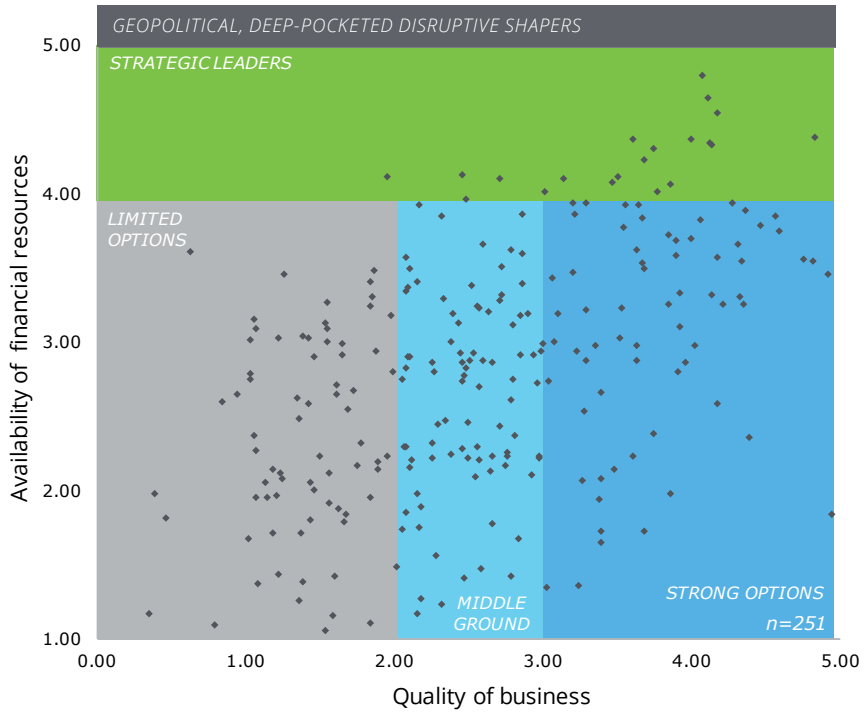
The map reveals hidden patterns – If the eye can see them

Geopolitical, deep-pocketed disruptive shapers – unbridled power to shape the industry

The largest industry shapers are typically either state-run oil companies, large oil or diversified manufacturers with existing and large-scale chemical assets, or large companies from outside the industry. They have substantial financial resources at their disposal and, in some cases, the backing of national governments to venture out and establish their foothold in other markets.[34] Their chemical businesses do not publish separate financial reports and if they are oil-and-gas players, they tend to be vertically integrated, which makes it difficult to compare them to publicly listed companies. Therefore, while these companies are considered for their disruptive potential, they are not included in the following analysis.

In 2010, 'Geopolitical, deep-pocketed disruptive shapers' were studied for their ability to shape the market. Since then, evidence reveals they are playing a significant role in chemicals markets. After the shale gas boom and the dramatic drop in oil prices in 2013, these companies accelerated investments in large petrochemicals facilities and signaled their intent to compete in the chemical industry. For example, Shell restarted its chemicals concern when it reentered the olefins and polyolefin businesses. Sasol, Chevron Phillips, and other players have also started making bets on new chemical assets in the US. Chinese State-Owned Enterprises (SOEs) are becoming more competitive by taking a more active role in overseas acquisitions, while rationalizing their unproductive domestic businesses and assets. Saudi Aramco, the Saudi Arabian petroleum giant, has ventured downstream in the chemical value chain, and has inked a joint venture agreement with LANXESS, the German specialty chemicals company, to enter into synthetic rubber production.[35]

Figure 9: Global chemical companies plotted on the new categorization grid (2016)



Source: Deloitte Development LLC analysis of data from Capital IQ, May 2017.

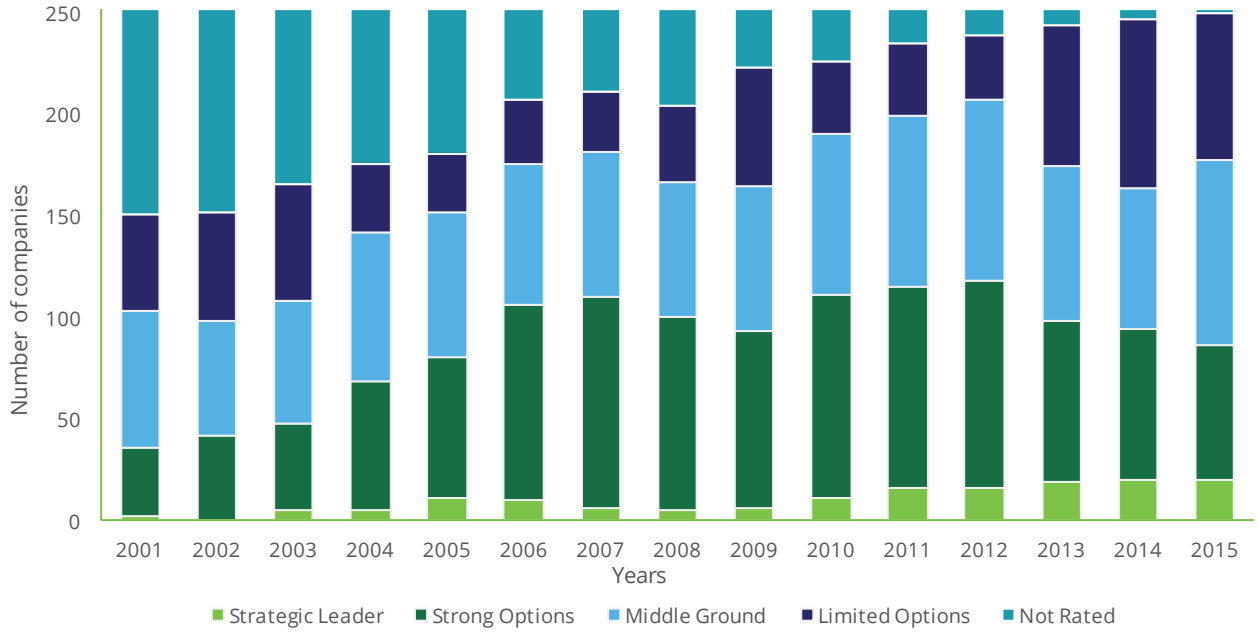
Strategic Leaders – well poised for the future but need for agility is imminent

Many of these 'Strategic Leaders' were more vertically integrated in the past than they are today. Once a major advantage, chain integration has recently come under pressure from activist shareholders believing there is more value in separating chained assets than operating as a vertically integrated manufacturer.[36] Most of the integrated chemical manufacturers today are either in oil and gas, are state-owned, or both. A few are privately held. These days, it seems that all (or all but a few) 'Strategic Leaders,' including those who once used size and scale as a competitive weapon, must learn how to be agile and able to grow by being open to innovations that could require venturing beyond their core businesses.

Opportunities for transformation exist. During the decade of 1999 to 2009, most 'Strategic Leaders' improved their fortunes. In the following six years, from 2010 to 2015, they further improved their financial position through productivity and efficiency gains, ventured out to do more acquisitions, and pruned their portfolios to focus on a few priority areas. The industry environment has also brightened since 2010, resulting in a healthy expansion in the number of companies in the 'Strategic Leaders' region of the map. As of 2015, 8 percent of total 251 chemical companies analyzed were 'Strategic Leaders' compared to only 5 percent in 2010 (see Figure 10).

'Strategic Leaders' have large financial resources at their disposal with their high cash reserves, operating cash flows, and unused debt capacity (see Figure 11). Despite this, 'Strategic Leaders' trail 'Strong Options' companies when it comes to ROA, ROC, and ROE. This indicates that the performance of 'Strategic Leaders' may be dragged down by certain underperforming pieces of their diverse portfolios. Meanwhile, 'Strong Options' players, which operate with greater focus in a smaller set of segments, have seen stronger profitability in performance.

Figure 10: New categorizations



Source: Deloitte Development LLC analysis of data from Capital IQ, May 2017.

Figure 11: Metrics for the new categorization

Availability of financial resources

Metric	Strategic Leader	Strong Options	Middle Ground	Limited Options
Total number of companies	21	67	89	72
Average cash on hand (2015)	US$2,253.2	US$332.1	US$395.4	US$260.9
Average cash flow from operations (2015)	US$3,424.9	US$708.9	US$464.5	US$199.1
Average interest coverage ratio (2012 to 2015)	16.8x	13.1x	6.7x	3.2x
Average EBIT/ depreciation (2015)	2.4x	2.8x	1.5x	0.9x
Average enterprise value net debt (2015)	US$33,410.8	US$7,473.8	US$4,624.0	US$2,883.5

Quality of business

Metric	Strategic Leader	Strong Options	Middle Ground	Limited Options
R&D as percentage of revenue (1998 to 2015)	2.7%	1.3%	1.1%	0.7%
Return on assets (1998 to 2015)	5.9%	7.5%	3.9%	1.0%
Return on capital (1998 to 2015)	20.7%	24.0%	12.3%	7.3%
EBITDA growth percentage (2012 to 2015)	12.1%	10.8%	19.1%	28.6%
Return on equity (1998 to 2015)	14.5%	16.7%	8.9%	3.0%

Note: Averages are calculated on a $US weighted basis. Dollar figures are in million units.
Source: Deloitte Development LLC analysis of data from Capital IQ, May 2017.

Strong Options – bringing value and differentiation but unimpressive profitable growth

'Strong Options' includes a significant number of iconic chemical companies that have innovated and built markets for decades. Their strength remains their ability to not only differentiate, but also realize the value of that differentiation. In 2016, as in 2009, 'Strong Options' companies continued to be the most valuable on the map. These companies have become attractive acquisition targets for both 'Strategic Leaders' and other companies in the 'Strong Options' category. This is a key reason why the percentage of companies in this category decreased over the years. Another significant reason is the difficulty of sustaining the level of performance required to stay in 'Strong Options' (see Figure 10).

Companies in 'Strong Options' display strong operational performance on almost all relevant metrics (see Figure 11). Although they remain far behind 'Strategic Leaders' in terms of availability of financial resources, they are highly successful in putting these resources to good use. This is driven by their level of focus and, in most cases, by avoiding chain economics. However, growth in profitability of 'Strong Options' companies has not been as impressive as it has been historically, especially over the last three years. 'Strong Options' companies have the lowest EBITDA growth figures among all categories between 2012 and 2015; some of it driven by the changing market conditions and oil prices. However, companies in 'Strong Options' can continue to remain strong performers by making more efficient use of capital and cash at their disposal.

Middle Ground – scope for much improvement

The percentage of chemical companies in 'Middle Ground' has increased over the years, indicating that a few chemical companies might have regressed from 'Strong Options' because they could not keep pace with the industry as it improved or transformed (see Figure 10). However, the largest factor behind the expansion of the 'Middle Ground' is the vast improvement of market and in industry fundamentals since 2010. This rising tide lifted several 'Limited Options' companies into the 'Middle Ground.' However, companies can rightly be worried about what may happen if the tide recedes again.

The 89 companies in the 'Middle Ground' category continue to be better off than their 'Limited Options' peers and, in some metrics, even better off than 'Strong Options' and 'Strategic Leaders.' 'Middle Ground' companies generally have better cash reserves than their 'Strong Options' peers (see Figure 11). Similarly, they have comparatively better profitability growth than 'Strong Options' companies and 'Strategic Leaders.' However, they continue to suffer from comparatively lower returns on their assets and capital, which is cause for concern about their ability to effectively and efficiently employ their financial resources.

Limited Options – truly limited for the future

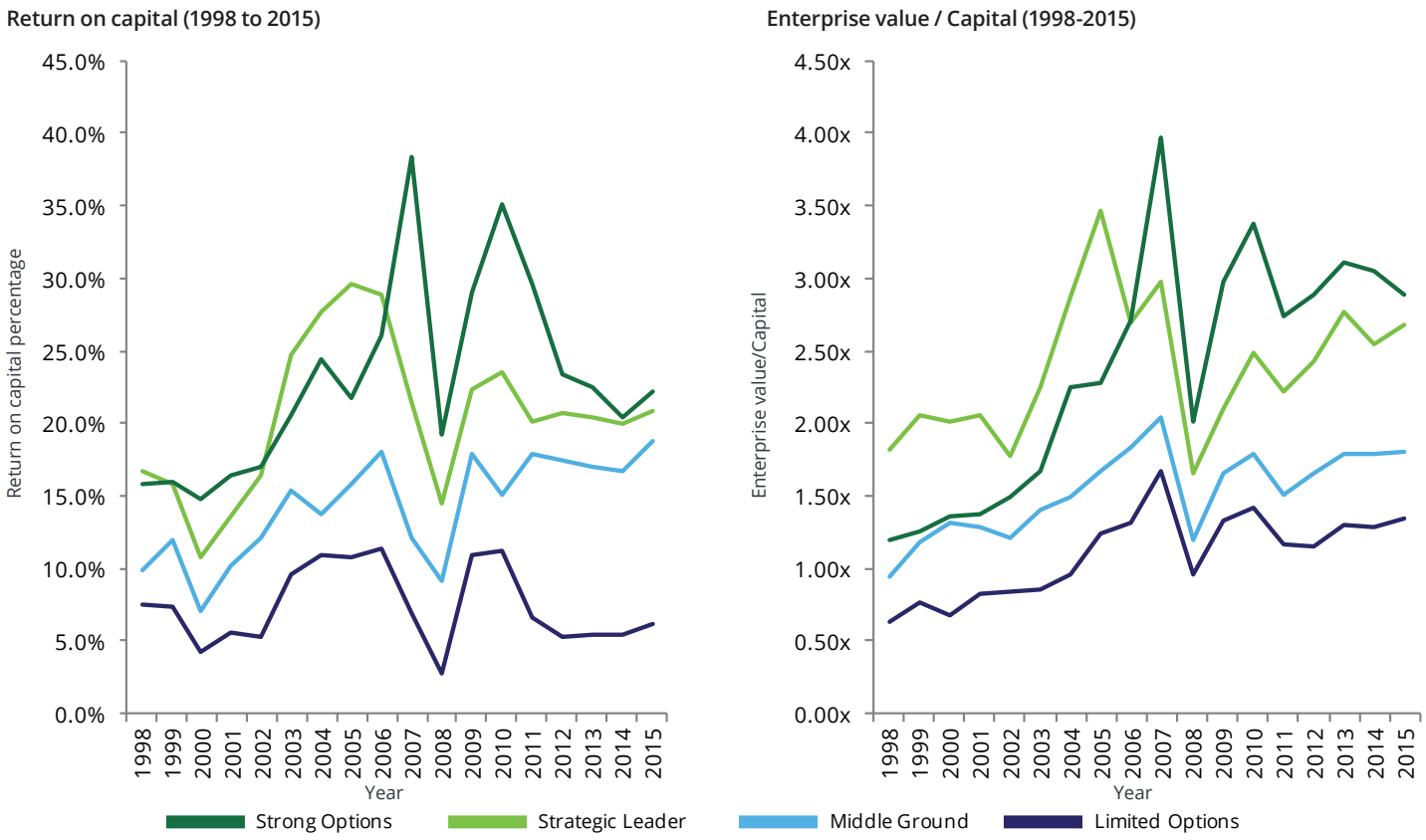
The percentage of companies with 'Limited Options' has been volatile over the years. Recent increased membership indicates that this part of the industry is still struggling. In 2009, 26 percent of total chemical companies landed in 'Limited Options' and then grew to 29 percent in 2015. However, it should be noted that this percentage fluctuated from a low of 13 percent (2012) to a high of 34 percent (2015) in between (see Figure 10).

Looking at individual financial metrics, the companies in 'Limited Options' appear to be the most disadvantaged, and in most cases, have fewer financial resources available to them (see Figure 11).[37] In a large number of cases, the EBIT produced by these companies is just sufficient to maintain the current asset base. In terms of returns to their capital and assets, they are worse off. Despite this, they are in a better position than 'Middle Ground' companies to cover their interest costs. 'Limited Options' companies need to do a lot of things right in order show momentum, including fixing their core businesses to realize higher profitability.

Different strokes – visible bifurcation of the multiverse

Over the years, a clear divergence is visible in the performance of each group in the chemical multiverse (see Figure 12). Chemical companies in 'Strategic Leaders' and 'Strong Options' categories have consistently been strong ROC performers compared to those in 'Middle Ground' and 'Limited Options.' This stronger ROC performance has been rewarded by the market in terms of enterprise value multiples.

Figure 12: Diverging performance of categories



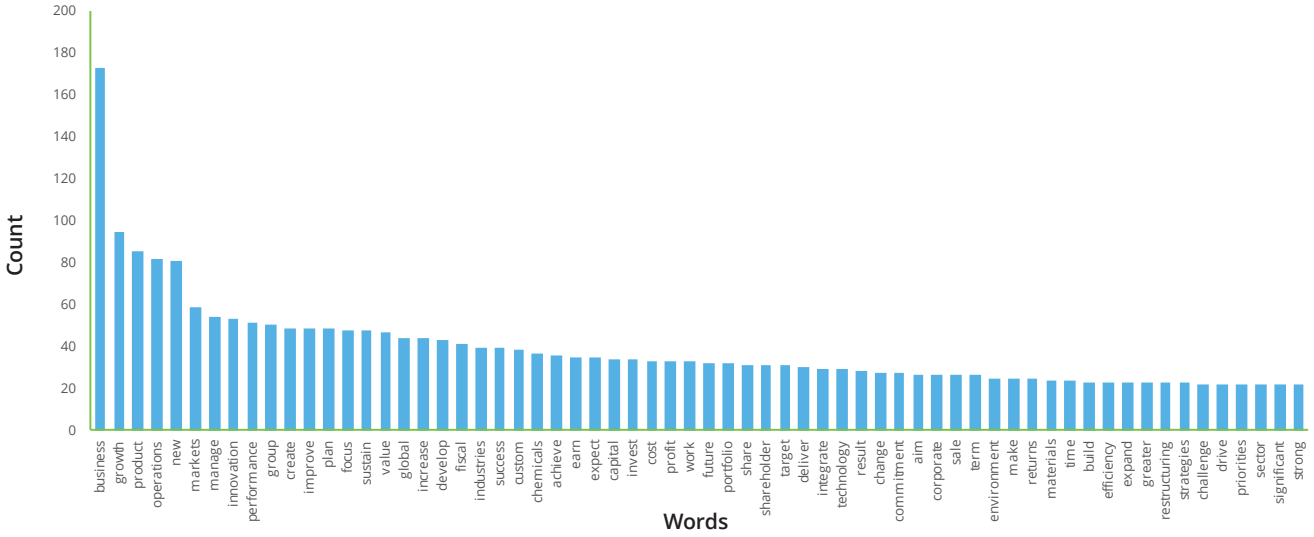
Source: Deloitte Development LLC analysis of data from Capital IQ, May 2017.

CEOs speak: What the "letters to shareholders" reveal

What are the C-suite executives at top chemical companies saying to their shareholders about their company's performance and its future course of action? Figure 13 is an analysis of the texts from the annual reports of top 11 chemical companies (by 2016 revenues). Specifically, the analysis looks at common themes appearing in the 2016 "Letter to stakeholders/shareholders" penned by each company's chairperson or CEO. This assessment used text mining and topic modeling packages. The specific focus was to not only find the most frequent words but also to categorize these words into broad themes.

Words related to business growth, products, operations, and markets were most mentioned in these notes. Similar analysis of 2011 versions of the letters reveals that while some of the themes have remained consistent, both the frequency and number of most frequent terms increased in 2016.

Figure 13: Most frequent single words in 2016



Note: Single words that occurred at least twice (on an average) in each of the "Letters to shareholders/stakeholders" for the top 11 chemical companies have been displayed here with their frequencies.
Source: Deloitte Development analysis, May 2017.

This same exercise with topic modeling was conducted in Figure 14. The topic-modeling algorithm categorizes the most frequent words (top 10) into different categories that help us understand the main themes within the document (without prior knowledge). Based on the most frequent words appearing under each of the six topics, the topics identified those of interest for chemical companies, as suggested by shareholder communication.

Figure 14: Common themes or broad topics

- Create and deliver business growth by realizing higher value from technologies
- Prioritize innovation and cost savings to realize continuous growth
- Return business focus to managing product portfolios
- Generate cash and earnings through restructuring led by group leadership
- Focus on long term by creating capital, increasing efficiency in allocation of resources and doing M&A activity
- Anticipate value-adding activities in the medium term, which can improve efficiency and meet challenges in the changing business environment

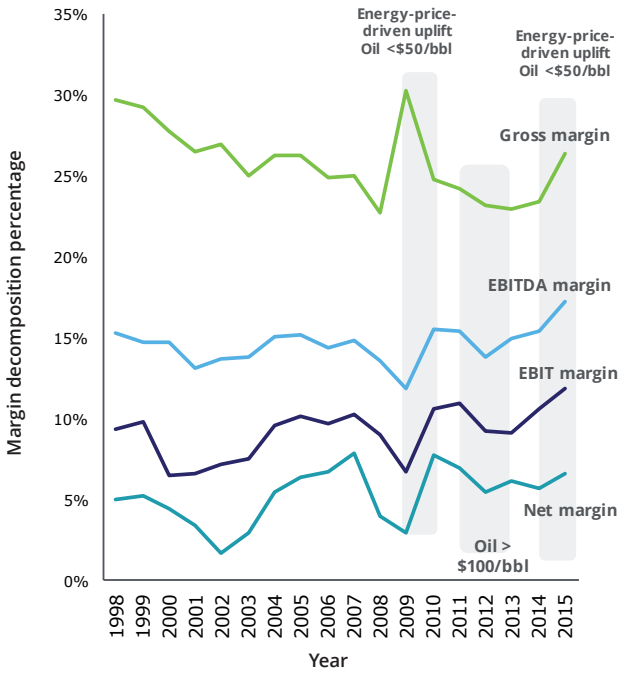
Source: Deloitte Development analysis, May 2017.

Where art thou, momentum?

It seems like the chemical industry has arrived at another inflection point. Many companies, while disciplined with their capital, have only recently started to realize higher profit margins (see Figure 15). ROC trends show the cyclicality of the industry and demonstrate that the cycles have not only become shorter but more frequent. Before 2009, the chemical industry's cycle of booms and busts averaged 10 years. Today, it has shrunk to two to five years. This indicates that while companies are getting better at maintaining balance-sheet discipline, there are still signs of increasing commoditization. Greater emphasis on operational efficiency and capital discipline has led to lower R&D spending and firms are struggling to define the next frontier of differentiation.

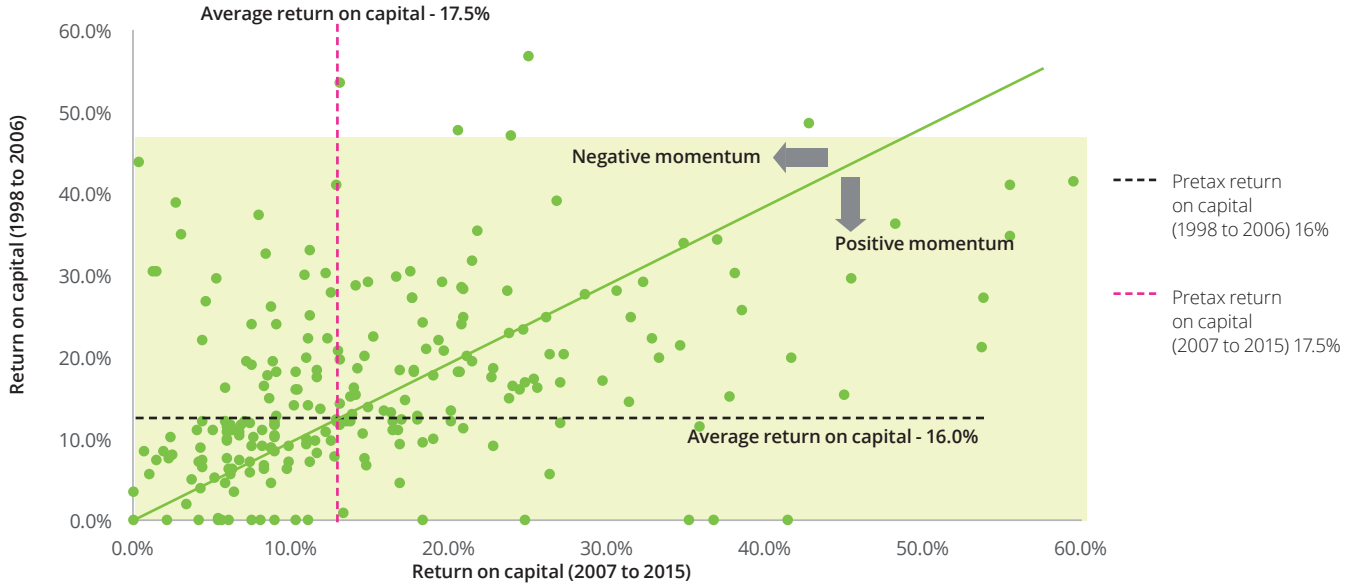
Chemical companies were not always so efficient with their existing capital. A comparison of data between the periods 1998 to 2006 and 2007 to 2015 reveals that the industry has raised the bar on ROC performance. The average pre-tax ROC has increased from 16 percent in 1998 to 2006 period to 18 percent in 2007 to 2015 period (see Figure 16). However, less than half of companies lie below the diagonal in Figure 16, indicating that despite a steady improvement in ROC, a majority of chemical companies struggled with a slightly lower profitability. This raises a question about how long the industry can continue its momentum of improving returns.

Figure 15: Margin decomposition for the chemical industry



Source: Deloitte Development LLC analysis of data from Capital IQ, May 2017.

Figure 16: Return on capital improvement since the last decade

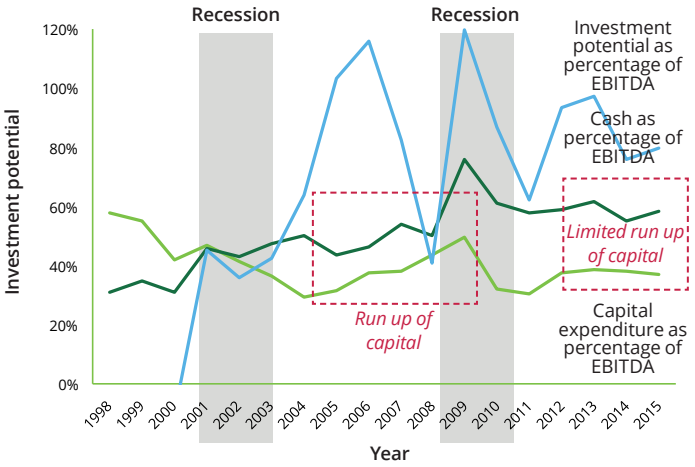


Note: Averages are calculated on a $US weighted basis.
Source: Deloitte Development LLC analysis of data from Capital IQ, May 2017.

Clearly, the industry has become more disciplined and conservative with capital. Only a fraction of significant projects announced in 2007 to 2008 and 2010 to 2011 actually came on stream. While many were delayed or cancelled (or assets mothballed), some projects did go forward when the market slowly rebounded. One additional trend was that chemical companies slowly increased their debt levels, given the potential for rate adjustments. Subdued demand, weak GDP growth, residual uncertainty resulting from the great recession (reset versus rebound), as well as the fact that it is no longer so attractive to invest in emerging markets, are likely contributing factors to this conservative stance. Less than promising results of regional expansion combined with significant pressure from investors has been another element in the rise of capital discipline. As a result, there is a large and growing surplus of cash, high enterprise value, and underutilized investment potential (see Figure 17).

This condition also highlights the difficulty of driving growth in this industry and how actions beyond the core business may be bigger determinants of a company's fate today than in the past. Although investment potential is high, there is also a slow, steady realization that the chemical industry is maturing. Completing an analysis, about US$155 billion worth of investment potential is lying dormant across 250 companies (see Figure 18). It is notable that the amount of investment potential varies by region, with Europe and the US on top and China and South America trailing the pack. (see Figure 18).

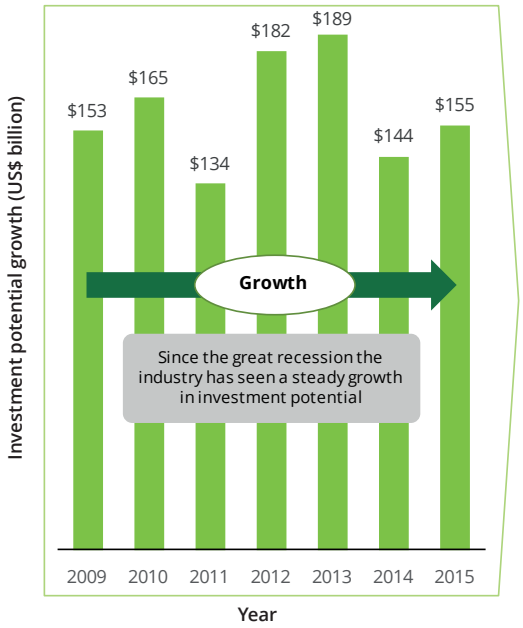
Figure 17: Capital conservatism and investment potential displayed by the chemical industry



Note: Investment potential = 3x (Average EBITDA) - Net debt -(1/2 Gross property, plant and, equipment [PPE] - net PPE)
Source: Deloitte Development LLC analysis of data from Capital IQ, May 2017.

Figure 18: Investment potential across regions

Investment potential growth



Source: Deloitte Development LLC analysis of data from Capital IQ, May 2017.

Where does the investment potential reside?

	Total assets (US$ millions)	Investment potential (US$ millions)
Europe	$377,157	$83,995
US	$432,768	$39,307
Japan	$275,217	$26,649
Middle East	$147,604	$23,094
Australia	$15,837	$1,452
Commonwealth of Independent States	$3,011	$919
Africa	$2,142	$722
Asia (ex Japan)	$158,577	-$1,748
South America	$20,622	-$2,299
China	$215,060	-$17,481
Grand total	**$1,647,995**	**$154,609**

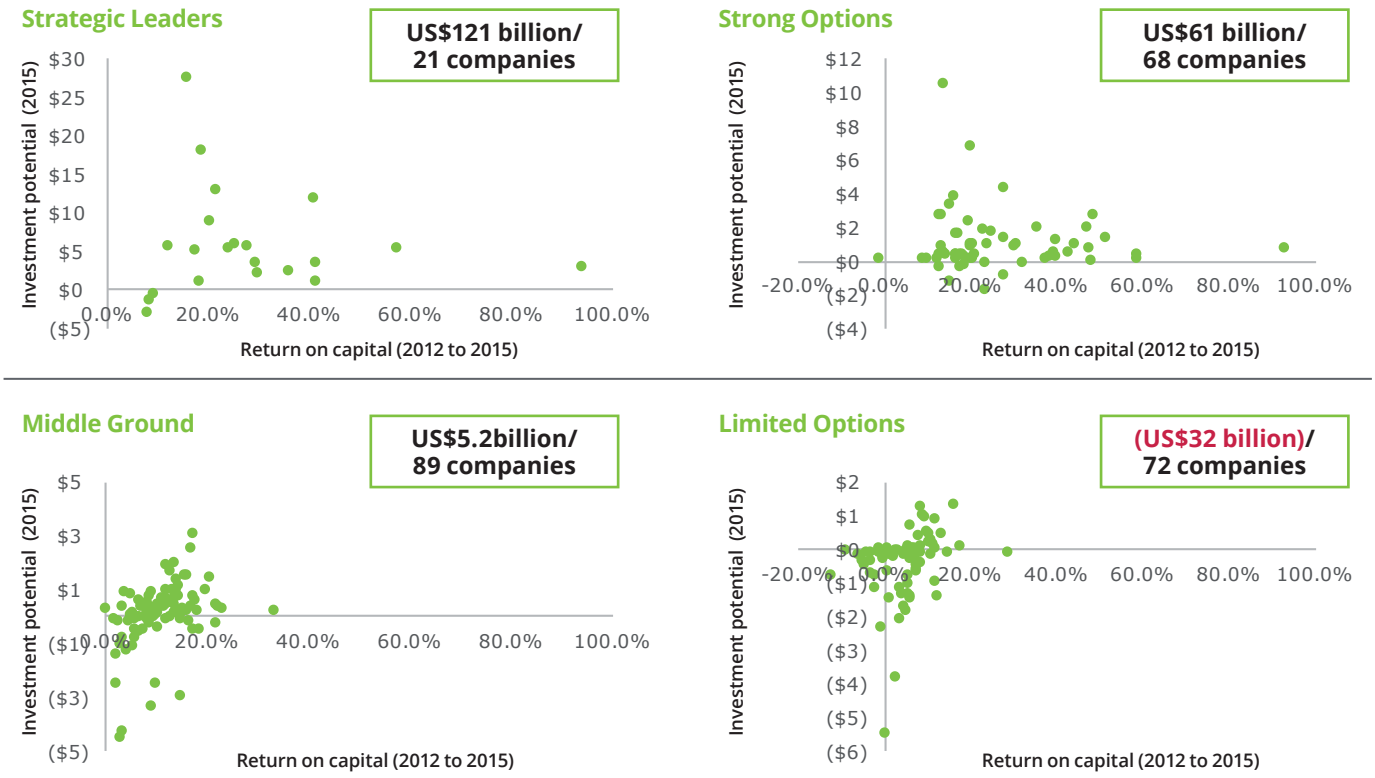
Lower investment potential in China is due to the cost of recent capacity additions. In dollar terms, the pace of chemical investments in China is expected to decrease in 2017 and 2018, as the sector grapples not only with overcapacity issues but also decreased demand.[38] Overcapacity is a likely cause for concern because of four key factors: (1) fragmentation in certain segments, (2) fiscal policy directives that induce provincial governments to build excess capacity to meet targets, (3) weak implementation of regulations, and, (4) preference for higher market share over profitability. Some of the key chemicals like polyethylene, poly vinyl chloride (PVC), methanol, nylon 6, caprolactum, chlorine and phosphorus pentoxide saw 70 percent or lower capacity utilization in 2015.[39]

Assessing momentum by new categorization

Based on earlier categorization of chemical companies into 'Strategic Leaders,' 'Strong Options,' 'Middle Ground,' and 'Limited Options,' Figure 19 shares how well each company is positioned with respect to its investment potential and profitability performance.

Figure 19 reveals that momentum lies with 'Strategic Leaders' and 'Strong Options' companies. Both these groups count on both high investment potentials and strong returns. On the other hand, companies in 'Middle Ground' and 'Limited Options' can barely meet their debt and maintenance capital obligations with their free cash flows, and therefore, have lower investment potential.

Figure 19: Investment potentials by new categorization



Note: ROC = EBIT/(Net working capital + Net fixed assets). Investment potential = 3 times EBITDA – Net debt – 0.5 x Gross PP&E + net PP&E
Source: Deloitte Development LLC analysis of data from Capital IQ, May 2017.

What lies ahead?

No matter the size or financial position of a company, going forward, virtually every company in the chemical industry will likely be affected by issues related to end markets, talent, advanced technologies, and new business models. The following section analyzes these important trends.

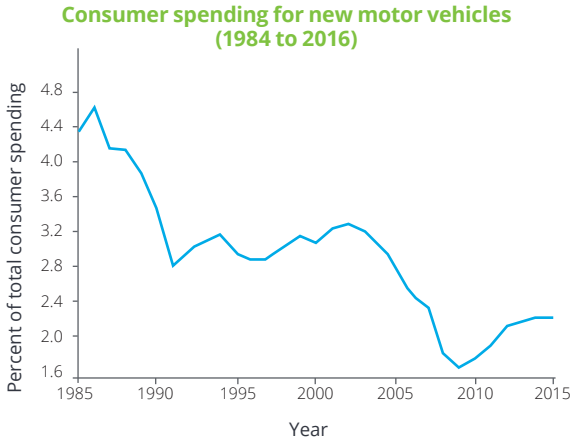
Trends in end markets—that reveal promising future demand

As we discussed in *End market alchemy*, some end markets, such as consumer products (e.g., personal care), medical devices, and food and nutrition, posted solid, post-recession growth.[40] The Chinese economy was growing and that boosted the demand in almost all the end markets. However, some industries, such as automotive, housing, construction, and manufacturing, were more strongly impacted by the great recession and, like the chemical industry, were forced to rely on resilience and discipline.

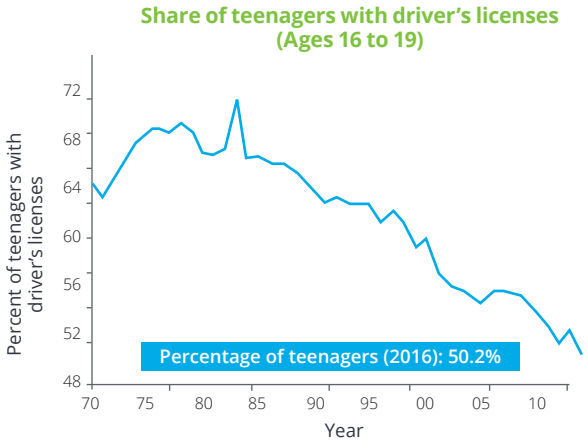
Over the last three years, US light-vehicle sales have risen at an annual rate of 6 percent and demand for chemicals and materials increased accordingly.[41] In addition, as vehicle fuel emission norms are further tightened, the proportion of chemicals and materials going into an average automobile to make it lightweight and fuel efficient will likely rise even more, and contribute to demand. So, while US light vehicle sales will stabilize at around 17 million units in 2017 and 2018, the penetration of chemicals is expected to further increase.[42]

However, consumer spending on new vehicles has decreased substantially since the 1980s and fewer teenagers in the US hold driver's licenses. Ownership may trend lower in the face of shared transportation models (see Figure 20). The automotive sector in Europe is in a mature phase with slow sales growth expected due to high prices and tight lending conditions.[43] However, Europe's stricter emissions norms are pressurizing more carmakers to use advanced, lightweight products. Furthermore, new technologies, such as 3D printing, are making headway into the typical automobile and are expected to further increase demand for automotive chemicals and specialty materials. In China, increased safety, fuel, and environmental standards are fueling the use of many chemicals despite a recent slowdown in demand.[44]

Figure 20: Trends affecting US automobile demand



Source: Deloitte Development LLC analysis of data from US Bureau of Economic Analysis and Haver Analytics, accessed in May 2017.



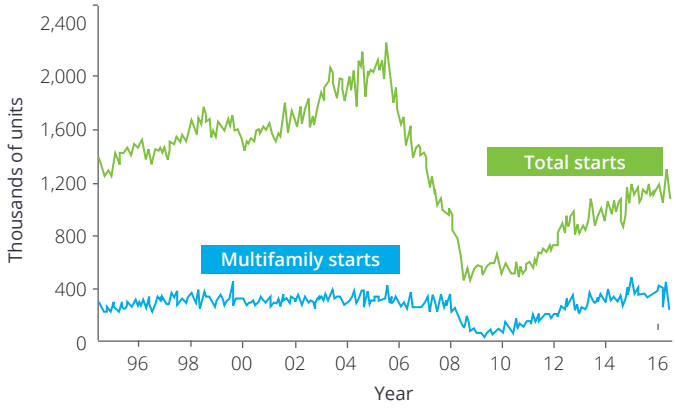
Source: Deloitte Development LLC analysis of data from US Census Bureau, Department of Transportation, and Haver Analytics, accessed in May 2017.

The outlook for the US housing and construction sector also appears promising. Driven by historically lower interest rates, low inventories, and gains in employment and wages, new housing starts are expected to increase to 1.28 million units in 2017 from 1.16 million units in 2016.[45] However, the figure remains far below the pre-recession levels entirely due to low single-family construction (see Figure 21). That said, an above-average growth rate in overall construction spending, as well as increased activity in energy infrastructure across the US, bodes well for the US chemical and specialty materials sector in the near future.[46] Construction activity in Europe has been particularly steady and is expected to see growth of close to 3 percent per annum until 2020, with new residential construction and civil engineering segments leading the way.

Ongoing private-sector initiatives in housing and construction sectors aimed at increasing efficiency typically look at energy consumption. The European Union is also tackling this issue with initiatives promoting the use of green and sustainable chemicals and materials.[47] Such policy impetus and new technological trends will positively affect demand for construction chemicals within Europe.

However, the Chinese construction sector is in the doldrums and the outlook for chemical demand is negative as annual real estate investment has fallen and the sector faces overcapacity with many newly constructed homes lying vacant.[48] As China is one of the largest consumers of construction chemicals, the impact of this downturn will likely be felt across the globe.

Figure 21: Housing starts in the United States (1994 to 2016)



Source: Deloitte Development LLC analysis of data from US Census Bureau and Federal Reserve Bank of St Louis, accessed in May 2017.

Among non-industrial segments, agriculture is leading the way. Demand for a variety of agrochemicals is being driven by growing populations and declining acreage of arable land. As a result, crop protection and enhanced yield have become even more important for farmers. Europe is expected to be the fastest growing region for agrochemicals, with precision farming (which enables more efficient use of water) and fertilizers leading the way.[49] China's agricultural sector is also a major demand channel for chemicals. Besides being the largest agrochemical market by revenue, the Chinese agrochemicals market also has one of the highest growth rates in the world.[50]

The talent imperative—driven by demographic changes

Demographic changes in the manufacturing workforce, including chemicals, may be challenging if companies do not take steps to address them. More than 8 in 10 US manufacturing executives already agree that there is a talent shortage in the industry.[51] Currently, finding the right talent for a highly skilled position is taking an average of more than three months. In addition, there is a wave of baby boomer retirements coming, and approximately 2 million jobs are expected to go unfilled (out of total 3.5 million jobs) between 2015 and 2025.[52]

The image of industry plays a key role in this issue. Although the general public recognizes the importance of a strong manufacturing base, people are less convinced about pursuing a career in manufacturing for either themselves or their children. Perceptions about compensation, working environment, and the nature of the work are generally negative. Potential candidates are misinformed about how clean, safe, and technology-oriented manufacturing working environments have become.[53]

Chemical producers should explore new models of workforce engagement, models that have already been successful in other industries. They should promote a flexible culture where decision making is not hierarchical, but rather flat and every employee can voice their opinion. In order to attract the next generation of the workforce, they can further highlight the tech-savvy nature of the industry – a feature that millennials find appealing. They can stress exciting new projects and innovation opportunities, work-life balance and platforms for cross-functional and cross-geographic teams that could make the chemical industry a destination of choice. Furthermore, chemical manufacturers should look forward to creating a more diverse workforce, as diversity leads to higher productivity among employees.[54] Among other initiatives, this also means recruiting, developing, and retaining women. Chemical manufacturers are well-poised to do this by highlighting the factors which appeal to women job aspirants like attractive pay, challenging and interesting assignments, and good work-life balance.[55]

Interestingly, while some fear the advent of artificial intelligence (AI) for the possible job losses that could result, people with disabilities may get new opportunities as AI can facilitate their entry into the mainstream workforce.

Emerging technologies—digital to impact across functions and value chains

Digital and exponential technologies present an incredible opportunity to every segment of the chemical industry. Many refer to this movement as 'Industry 4.0' or the fourth industrial revolution. It essentially represents "the technological evolution from embedded systems to cyber-physical systems,"[56] and encompasses relevant physical and digital technologies, including analytics, additive manufacturing, robotics, high-performance computing, AI and cognitive technologies, advanced materials, and augmented reality.[57] Digital enablement through Industry 4.0 makes physical, task-performing machines intelligent enough to take appropriate decisions of their own without much human intervention. Digital Manufacturing Enterprise or DME effectively employs Industry 4.0 to drive a chemical enterprise's competitiveness.

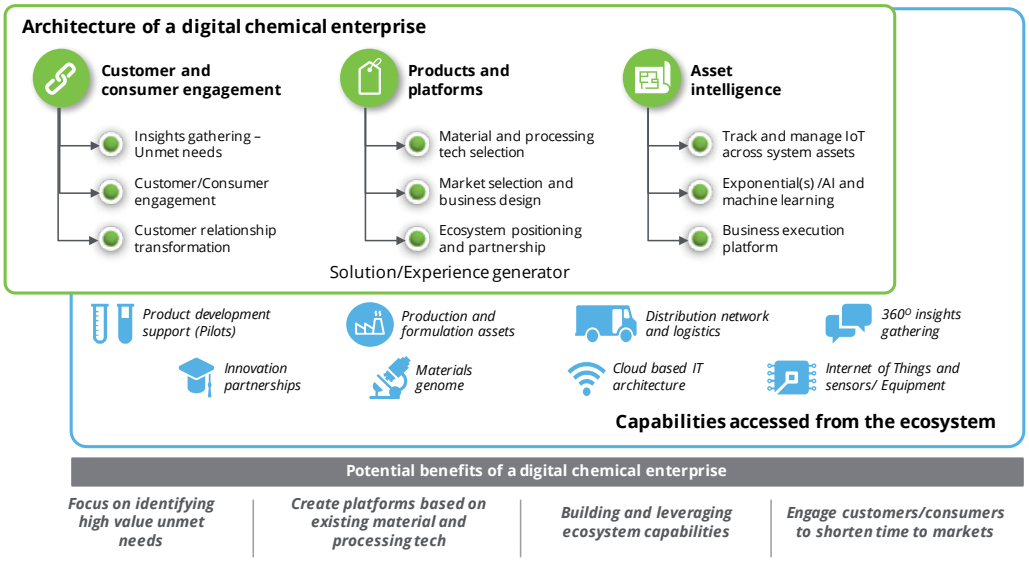
Given the costs (both financial and human) of traditional R&D, it likely comes as no surprise that manufacturing executives are placing significant bets on DME technologies. Digital is increasingly viewed as the next frontier of efficiency improvements, with a focus on efficiently balancing supply with external requirements. Could digital leadership become a central element of competition in manufacturing? Manufacturing executives appear to think so. In a 2016 survey, predictive analytic, Internet of Things, smart products and smart factories, and advanced materials were ranked as critical to future competitiveness.[58] Chemical executives have expressed similar priorities.

Saying and doing are two different things and although executives realize the increasing importance of these technologies, their approach thus far has been cautious. As revealed in Deloitte Global's inaugural *2016 Global Digital Chemistry Survey*, more than 4 in 10 chemical executives expect their companies to be more digital than their competitors in the future. At the same time, more than five in 10 executives concur that their organizations lack a digital transformation strategy.[59]

One of the main reasons likely behind such conservatism is the lack of knowledge or low confidence in the potential benefits of a digital transformation. This has limited chemical enterprises to make only marginal changes to existing processes and systems. While the implementation of digital comes with its own set of challenges, the advantages far outweigh the costs. Chemical enterprises, which have already leveraged the power of DME technologies, have experienced several benefits (see Sidebar entitled "Enhancing capabilities: The role of DME technologies").

Technologies comprising the DME are both physical and digital, giving chemical companies a complete suite of advanced technologies to use to help make their assets intelligent, enable new platforms for growth, and engage and satisfy the customer and the consumer. In essence, DME as it applies to the chemicals industry, can potentially bring together asset intelligence, an understanding of the full asset base, and a digitally engaged set of customers, suppliers, employees, and markets in order to create targeted products and platforms in the industry (see Figure 22).

Figure 22: Vision of a digital chemical enterprise (adapted from a digital manufacturing enterprise model)



Source: Deloitte Development LLC analysis, May 2017.

Enhancing capabilities: The role of digital manufacturing enterprise technologies

The role of digital in enhancing customer experience and engagement

- **Insights gathering—unmet needs:** Machine learning and predictive analytics can enable more accurate demand sensing as well as mass customization to match offerings to individual customers' needs and behaviors.
- **Customer/Consumer engagement:** Anecdotal evidence suggests that many companies (including chemical) have already launched mobile apps to enhance customer service and engagement. Chemical companies are also creating fully serviced, self-driven, and web-enabled platforms to manage the end-to-end customer experience seamlessly.
- **Customer relationship transformation:** Rigorous analysis (using advanced analytical techniques) of the point-of-sale data can send the chemical manufacturer in the right direction and provide end-consumer visibility. Through advanced analytics, using real-time data, leading chemical companies can also address unique customer needs by differentiating their service offering capabilities into multiple, value-chain-specific segments.

Can digital platforms fulfill the promise of future growth?

- **Material and processing technology selection:** Online repositories containing information about relevant chemicals and materials for research are already enabled by digital developments like lower data-storage cost, high-performance computing and advanced analytics. Moreover, with supercomputing facilities available, it is now easier and faster to perform material simulations. Supercomputing can also be used to 'reverse engineer' materials and chemicals so that chemical manufacturers start with the function they want in the final product and use computer simulations to back calculate the chemicals and materials that are most compatible to achieve the desired properties. Once done, chemical manufacturers can use advanced prototyping techniques, like 3D printing, and then test the product physically using software like computer-aided design.
- **Market selection and business design:** Digital technologies like cloud computing and architecture patterns help enable quick and agile business decision making. Cloud-computing solutions generally lead to reduced cost of operations, enable virtualization and higher visibility of processes and operations, and better justification of digital dollars spent.
- **Ecosystem positioning and partnership:** With Industry 4.0 connectivity, monitoring, and analytics, chemicals companies can have direct visibility into and interaction with their customers' operations, and can provide real-time recommendations to optimize the operations and improve the design of their facilities. At the same time, crowdsourcing platforms, enabled by digital technologies, can not only help gauge consumer sentiment about a new product, but also generate ideas and concepts about what can be improved to make it more appealing to the target segment.

What can digital do for chemical assets?

- **Track and manage Internet of Things across system assets:** Industry 4.0 technologies can be leveraged to make the chemical plant more efficient by anticipating real-time demand and optimizing resource utilization around it. Demand sensing can help improve inventory turns and reduce safety stock, resulting in lower working capital costs by providing a more accurate demand signal. Some chemical companies are, in fact, able to predict maintenance downtimes and optimize the coordination of maintenance and production processes by using such technologies.
- **Exponential(s)/Artificial intelligence, and machine learning:** Chemical companies have greater tools at their disposal to predict and automate certain tasks, whether at the factory or the supply-chain level. Some organizations have assessed and built out their capabilities in analytics, risk management, and business-partner collaboration to include track-and-trace technologies, as well as predictive modeling for logistics management. Modeling chemical processes based on historical records by machine-learning methods, like neural networks, support vector machines, and decision trees, enable performance and condition monitoring of chemical plants.
- **Business execution platform:** Support services and execution of repetitive internal business tasks can be made smart and automated through digital technologies. Some chemical companies have built internal digital platforms for standardizing, automating, and visualizing financial reporting across their organization.

Source: Deloitte Development LLC analysis, May 2017.

The chemical industry is likely not going to change its attitude towards digital overnight. The process might be slower in some segments, faster in others. But no one can ignore the transformation that is taking place across its value chain. The potential benefits are likely enormous. On the customer level, it means being able to engage more productively with the end user, to understand and anticipate their unmet needs, and how they influence other players in the industry. Products and their platforms can be developed faster and more precisely and with less need for upfront capital. Finally, assets can see higher network utilization, benefitting from a more complete understanding of a company's assets (see Figure 22).

Every chemical manufacturer should at least monitor digital trends both within its industry, as well as across the value chain. The effects of digital adoption are somewhat borderless and its impact ripples across end-use industries and value chains. Keeping this in mind, chemical executives can take appropriate steps towards their organizations' transition to the digital chemical manufacturing enterprise. It all starts with a robust strategy or roadmap, which would properly lay out the steps of the digital journey. These steps are explored deeply in the report *Digital transformation: Are chemical enterprises ready?* [60]

This revolution is already underway and the chemical industry is late to the table. In many ways, the laggardness of chemical companies might be a boon; they can learn from the mistakes other industries have made and about the pitfalls to avoid. Despite this, the digital journey will come with challenges that may seem initially daunting. However, with a clear vision about what to do and what not to do with their digital enterprise strategy, chemical companies can avoid dangers and make theirs a success story.

The future of new product development using 'in-silico' material design

In principle, the theoretical tools needed to calculate the properties of simple atoms and molecules have been available since the discovery of quantum mechanics in the early 20th century. The resulting mathematical tools led to rapid advances in the ability to predict atomic scale properties. These predictions were confirmed with advanced analytical and characterization techniques and this led to rapid advances in physics and molecular modeling of simple compounds. Unfortunately, the field of material science was almost left out from these advances.

The problem was one of scale. It is one thing to mathematically model a hydrogen atom (one electron) or hydrogen molecule (two electrons) but it is quite another to solve equations for properties on the scale of macromolecules, ceramics, and metal alloys (materials with relevant size scales thousands of times larger than an atom). However, today's companies are now coming into an era where it may become possible to use atomistic calculations to design materials with specific and desired chemical, electronic, and physical properties. In other words, 'in-silico experiments' can come to replace (or at least significantly enhance) classical laboratory experiments.

So what has changed to make 'in-silico experiments' part of the material designer's toolbox? Since the mid-1980s, the convergence of three trends, coupled with the emergence of an entirely new capability, have catalyzed the field of computational material science. This convergence has involved well-documented advances in computational power and availability, the development of analytical techniques, such as Atomic Force Microscopy (enabling measurement of properties on the same scale of the computer modeling) and the rapid development of mathematical approaches (called potential functions) that accurately reproduce structures and properties across many materials.

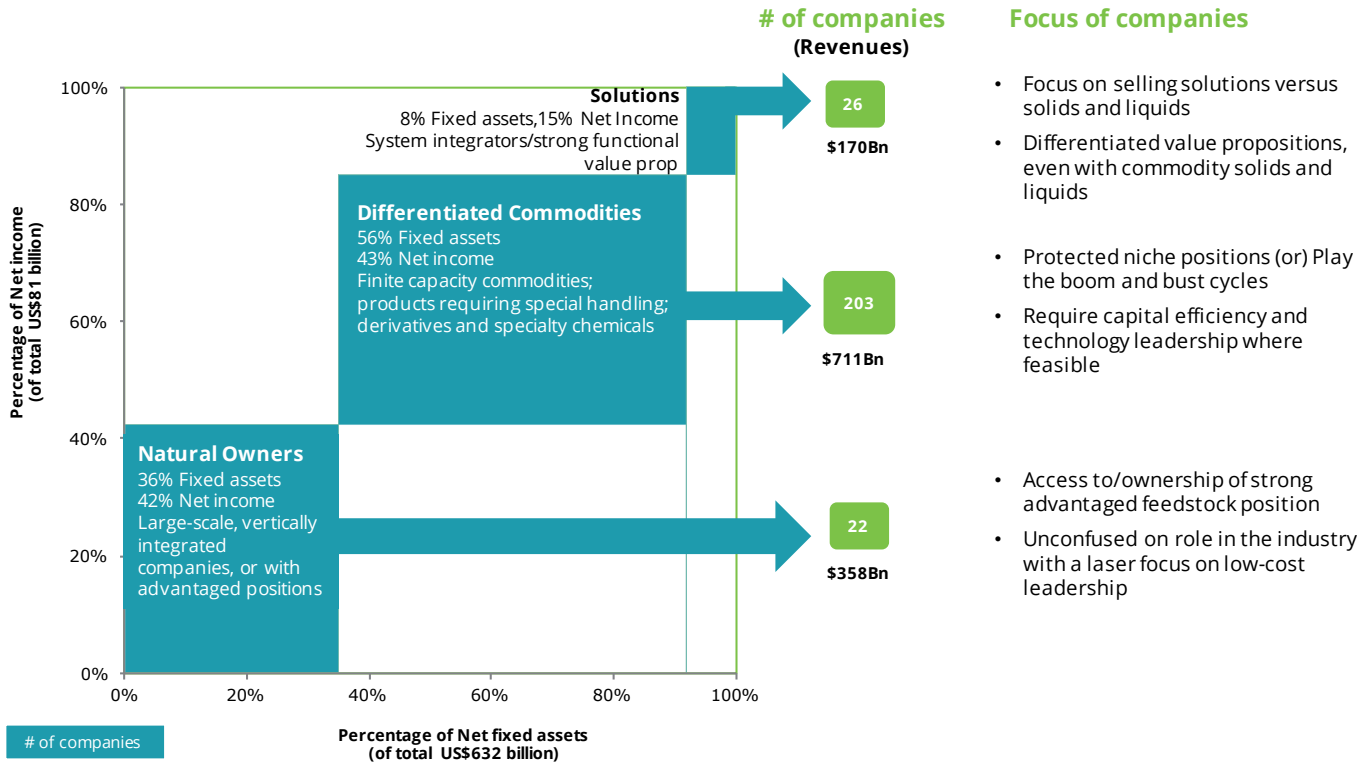
Additionally, machine learning has very recently emerged as an intriguing accelerant to 'in-silico' experimentation. Machine learning advanced from computer science, and the impact on experimental science could be just as great as any fundamental theory of nature. Leveraging the combination of molecular modeling based on quantum mechanics with machine learning capabilities holds great promise. As an example, one could use molecular modeling to design a new material with very specific physical and chemical properties and then use a machine-learning algorithm, such as neural networks,to suggest an economical and environmentally efficient synthetic route to that new material, all without setting foot in a laboratory.

Source: Deloitte Development LLC analysis of information from *MRS Bulletin, Three decades of many-body potentials in materials research, Volume 27*, p469, 2012; and Discussion with Dr. Susan B. Sinnott, Department Head, Material Science and Engineering, Penn State University, April 2017.

Business models—the new basis of renewed competitive activity

As a result of the recent activity discussed thus far in this paper, the following is a designed framework that can be useful for understanding the competitive dynamics of today's global chemical industry (see Figure 23).

Figure 23: New classification of chemical companies, based on income and assets



Source: Deloitte Development LLC, May 2017.

There is a sizeable and important subset of the industry called 'Natural Owners.' These are companies that tend to: (1) be more focused on the upstream side of the chemical value chain, (2) have strong feedstock/cost positions, (3) maintain dominant positions in markets with higher than normal barriers of entry, and (4) have strong balance sheets. This fosters clear business and operating models geared for maximum efficiency, as well as the scale to drive the market. As Figure 23 shows, 'Natural Owners' earn a healthy percentage of industry profits, especially when considering the overall number of companies and percentage of assets they operate.

At the other extreme are companies focused on solutions which sell an outcome, such as better crop productivity, and/or clean facilities, or a flavor/fragrance profile. Most have been successful for decades in bringing new products (bundled with services) and platforms to the market. A few chemical companies have been steadily transforming themselves into solutions providers in order to offset lower margins of their mature and commoditizing businesses. Success in the solutions space requires clarity in understanding how to bring innovative ideas to meet market needs.

However, it has become evident to us that a number of these market needs will require multi-disciplinary and collaborative approaches that will also push for a deeper understanding of the end consumer, whether in the business-to-business or in the business-to-customer space. This has been a challenge for chemical companies looking to shift their focus to solutions where the clarity of consumer needs is not evident, either by design or choice. The business models of successful solutions providers are often not price- or volume-focused. They tend to be very profitable and less asset-intensive. Recent evidence suggests that technology and non-chemical

Rapidly transforming chemical sectors: Changing market dynamics, feedstock pricing, and supply/demand balance

The year 2016 will go down as one to forget for global chemical producers. For downstream customers, however, it was a year to remember, as the deflationary pressures brought on by tepid economic growth, low hydrocarbon prices, low grain prices, and low interest rates, weighed on the sector's pricing flexibility. In 2017, C-suite executives may wonder if the expected rebound from the 2016 trough signals a more buoyant mid-term trend or if it will prove to be nothing more than a rebound from depressed levels.

Global crop protection and agricultural chemicals
The heady years of 2010 to 2013, when sales were boosted by the December 2007 US Renewable Fuel Standard (RFS) corn-based ethanol mandate, gave way to mid-single-digit sales declines in 2015 and 2016. The culprit was crop-price volatility resulting from a corn-acreage supply response to the RFS mandate, compounded by a corn-yield supply effect from four consecutive years of abundant harvests. This showed up in unfavorable top-line sales metrics (volume declines, price erosion) and was compounded by politically driven and unfavorable currency trends in Brazil and Argentina. Crop protection chemical producers (CPC) were especially hard hit by lower pest and weed prices, due to vigorous crops benefiting from good growing conditions. Prices will remain weak in 2017 due to excess CPC channel inventory in the value chain.

The resulting margin pressure is driving an unprecedented round of consolidation, with all five of the 'Big Six' slated to change ownership. This includes ChemChina's proposed acquisition of Syngenta AG and the proposed merger of equals between Dow Chemical and DuPont. However, not all mergers are primarily driven by margin pressure – instead unrealized potential synergies between complementary businesses is a major driver. An example of that would be the proposed acquisition of Monsanto by Bayer.*

For the balance of the decade, there are three price-driven scenarios:

- The baseline case is for modest sector revenue growth of just 3 percent per year based on grain and oilseed prices, rebounding in line with current futures curves for corn, soy, and wheat, which suggest crop price increases of just 2 percent per year.
- Case I is for 10 percent compound revenue growth 2017 to 2019 aligned to a sustained 20 percent bounce in crop prices, in line with the 10 percent compound growth the sector enjoyed 2010 to 2013.
- Case II is for 13 percent compound revenue growth 2017 to 2019 aligned to a sustained 30 percent bounce in crop prices, which is optimistic since that would well exceed the 10 percent growth discussed above.

*Source: Reuters, "Exclusive: ChemChina's Syngenta acquisition close to clearing U.S. review – sources," August 22, 2016, http://www.reuters.com/article/us-syngenta-m-a-chemchina-exclusive-idUSKCN10X038; The Dow Chemical Company, "DuPont and Dow to Combine in Merger of Equals," accessed on March 1, 2017, http://www.dow.com/en-us/news/press-releases/dupont-and-dow-to-combine-in-merger-of-equals; and Bayer Corporation, "Monsanto Shareowners Approve Merger with Bayer," December 13, 2016, http://www.press.bayer.com/baynews/baynews.nsf/id/Monsanto-Shareowners-Approve-Merger-with-Bayer.

manufacturing companies have remained focused on solutions, while commodity and semi-commodity chemical players are just starting out in this space. The latter, while well-positioned, should move quickly to seize the kinds of solutions-oriented opportunities that originate from evolving societal trends, as highlighted in Advanced Materials Systems paper.[61] In enabling all of this, innovation will play a key role and the market will likely continue to reward innovation and rapid commercialization going forward.

The largest percentage of assets resides in differentiated commodities that tend not to yield profits in proportion to their asset intensity. These companies are involved with a diverse group of assets, products, and markets. In some cases product, market, and customer combinations are too fragmented or too diverse to serve effectively. Historically, many of these businesses have benefitted from: (1) long-cycle product formulations and specifications, (2) limited supplier set, (3) diverse businesses with natural hedges to market conditions and, (4) enough differentiation to curb substitution. Many of these businesses produce healthy cash flows even as they continue to mature. In recent years, many have showed increased cyclicality and many could face challenges with capacity changes, regulatory pressures, and possible substitution (e.g., consumer driven).

Companies with most or all of their portfolios in differentiated commodities will likely have fewer options to grow organically and may be hard pressed to deliver profitability improvements through cost reduction. This group is also likely to be the most vulnerable to troughs in the economy, deflation of goods prices, and lack of pricing power when energy prices are low.

Advanced Material Systems: Framework for solutions development

Innovation in the chemical industry historically has been focused on molecule discovery or application development, all with a focus on selling a solid or liquid. However, with the changing landscape and the increasing rewards in solving many of the 21st century problems, no single industry can likely manage success without collaboration. Chemical companies looking to break the mold and move towards solutions, require a rethinking of traditional innovation approaches focused on molecules. In December 2012, the report titled *Reigniting growth, Advanced Material Systems* created a framework.[62] This helped to change the paradigm from molecule/applications-focused innovation to targeting end-market challenges and leading the solution development holistically with effective collaboration across an ecosystem of capabilities. A key premise in developing the framework was focused on the discovered or already-invented required materials and also processing technologies that can be used to produce and engineer functionality, as required (see Figure 24).

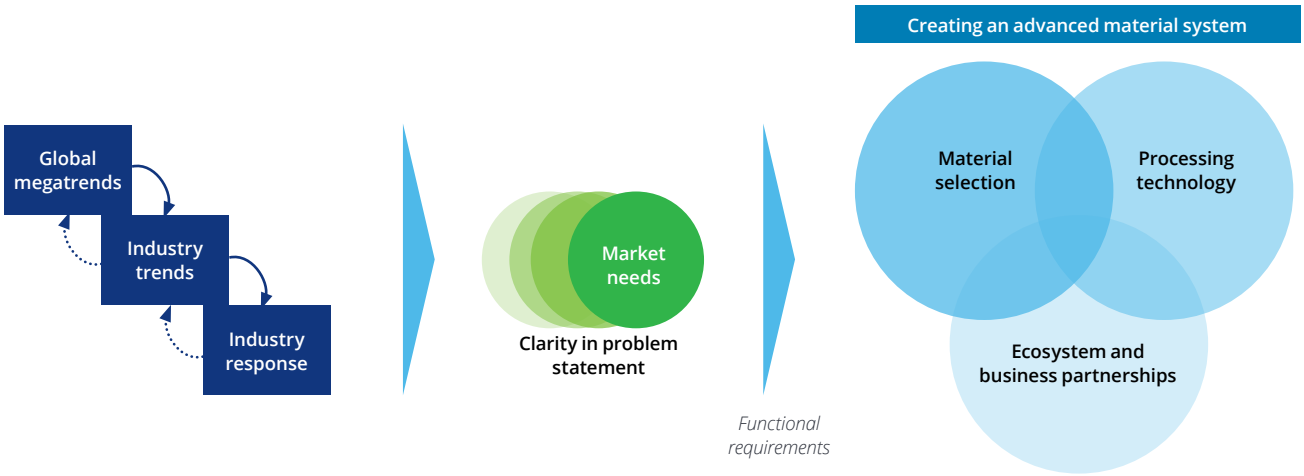
Key steps to creating a viable advanced material system that drives solutions business include:

- Clearly articulating the functional requirements needed to solve for market needs and break down the functional requirements into targeted engineering/business model related problems.
- Understanding and defining an ecosystem of capabilities. All the required capabilities do not likely reside within the four walls of a single enterprise.
- Creating an effective collaborative model to solve for each of the individual problems across the ecosystem.
- Owning the overall solution architecture and managing individual piece solutions to integrate into the whole.

In principle, these sound practical and easy to do, however given the long culture of innovation in the chemical industry, managing change to utilize a series of capabilities from across the the ecosystem has been rare to the industry. Not all companies will choose the solutions path. However, for those that do, shortening the product innovation life-cycle will be critical to the success of a solutions business. The tenets of the approach are being refined in government-funded research labs. Scientists in universities and investors around the world are looking at the potential of systems-level thinking and multi-disciplinary approach as catalysts for technology breakthroughs. New open innovation partnership announcements are happening with increasing frequency. This has the potential to disrupt the traditional chemical industry, however it is also a very big opportunity considering the scale of problems that humankind faces.

Source: Deloitte Development LLC, May 2017.

Figure 24: Creating Advanced Material Systems



Source: Deloitte Development LLC, May 2017.

Mid-term view of businesses

Global Petrochemicals

After a surge in 2010 following the great recession of 2009, volume growth for leading petrochemicals producers lagged GDP growth 2011 to 2015 and then rebounded to modestly exceed GDP growth in 2016. Following the oil price as a benchmark, petrochemical product pricing has been on a roller coaster, up 15 percent in both 2010 and 2011, flat during the three years 2012 to 2014, before plunging 15 percent in 2015 and a further 10 percent in 2016. Still, producers were largely successful in hanging onto unit margins, and EBITDA has managed to trend higher. Now, with oil prices set to rise as much as 25 percent in 2017, product pricing would be expected to rebound sharply were it not for a raft of new monomer and polymer capacity coming on-stream in the US Gulf Coast, Middle East, China, and India in 2017. This capacity surge is the natural response to the earnings recovery from 2012 to 2016.

For the balance of the decade, four oil-price-driven scenarios include:

- Baseline case is for sector revenue growth of 5 percent per year based on the oil price rebounding from the 2016 trough, rising 10 percent per year in line with current forward futures curves, with most of the oil price gain occurring in 2017.
- Case I is for 6 percent revenue growth 2017 to 2019 tied to a somewhat more robust 11 percent per year rise in the oil price.
- In Case II, sector revenues decline by 2 percent per year over the 2017 to 2020 period, albeit on a roller coaster. In this scenario, oil prices plunge 25 percent in 2018 to 2019, wiping out the 2017 gain, due the inability of OPEC oil production quotas to hold up.
- In Case III, sector revenues grow a very modest 1 percent per year over the 2017 to 2020 period as oil prices remain flat at 2017 levels over the forecast period due to lingering tepid global GPD growth.

Global industrial gases ("Big four")

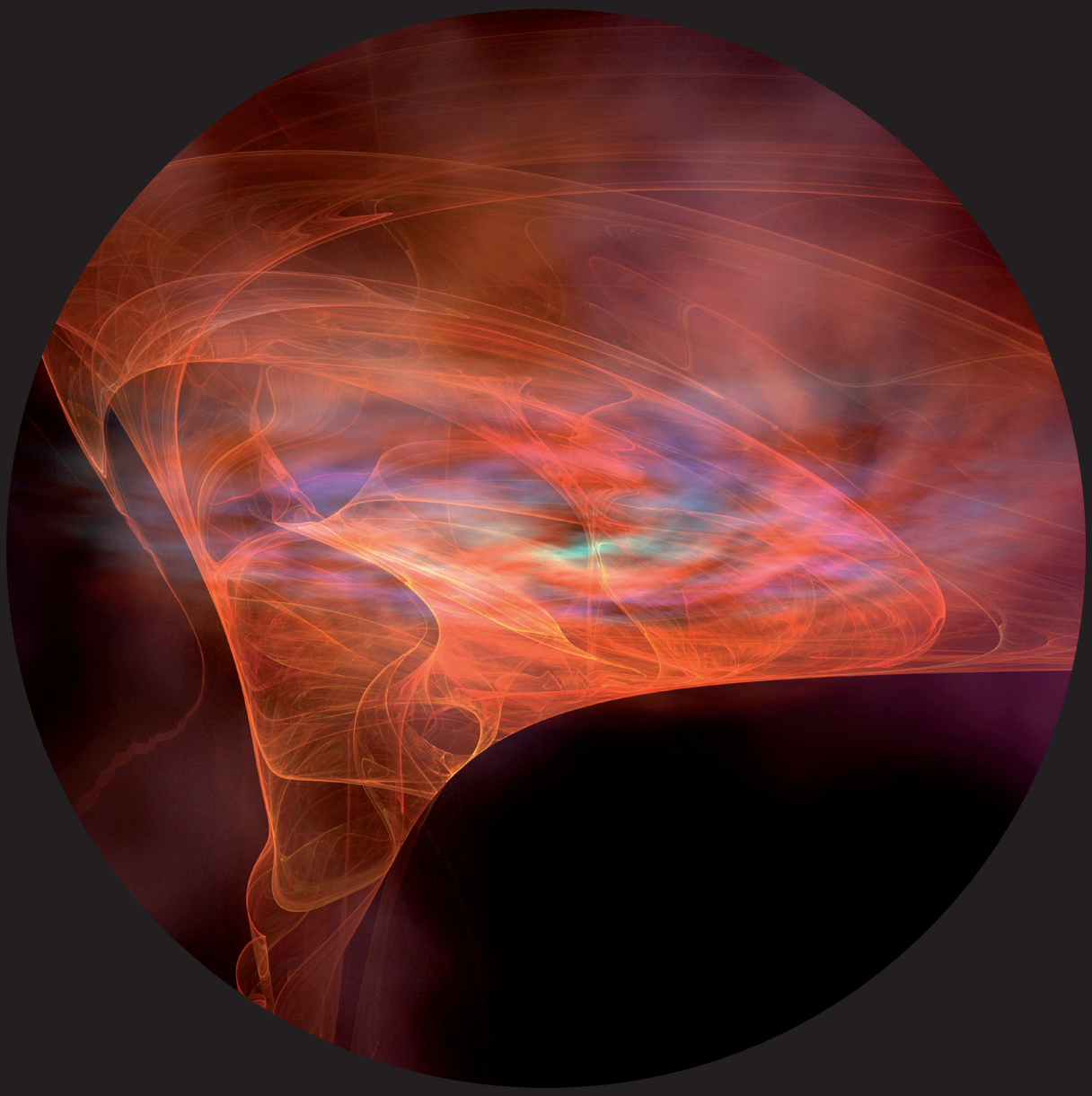
It has been a frustrating five years for the global industrial gas industry. Volume growth coming out of the recession was a robust 8 to 9 percent in 2010 to 2011. However, industry volume growth has been just at or below industrial production growth from 2012 to 2016 period. The '4 Es' (energy, emerging markets, electronics, and environment), which drove volume growth at approximately 1.5 times production growth during the 1990s and 2000s, are now long in the tooth, with no new drivers ready to fill the breach. Energy prices collapsed during 2015 to 2016; the BRIC emerging market story has faded (especially in Brazil and Russia); the microelectronics market is growing at just two times GDP growth; and environmental applications have largely been penetrated, at least in developed economies.

The prospect for tepid volume growth as the new normal is driving cross-border consolidation involving every member of the Big Four. Two are looking to merge, while the other two have acquired regional players. Praxair and Linde have proposed a merger of equals, Air Liquide acquired US packaged-gas leader Airgas in mid-2016.*

For the balance of the decade, three likely economic growth scenarios may unfold. Sector revenues in each case track GDP growth.

- Baseline case is for sector revenues growth of just 3 percent per year, based on GDP growth of 2.1 percent per year over the period.
- In Case I, sector revenues grow at 4 percent per year, as GDP growth ratchets up to 2.8 percent per year.
- In Case II, sector revenues grow at 1.7 percent per year as GDP growth is an anemic 1.5 percent per year, due to a recession in mid-2018.

* Source: Praxair, "Linde and Praxair Announce Intention to Merge," December 20, 2016, http://www.praxair.com/news/2016/linde-and-praxair-announce-intention-to-merge; and Airgas, "Air Liquide announces agreement to acquire Airgas," November 17, 2015; https://www.airgas.com/medias/2015-11-17-Press-Release-Air-Liquide-Announces-Agreement-to-Acquire-Airgas.



The path forward

Bifurcation will likely mark the near future of the chemical industry. The fissure puts the traditional model of producing and selling chemicals on one side and the solutions space on the other. The former will continue to be the domain of Natural Owners, who should continue to prosper, and specialized commodities producers, who will find operating margins increasingly compressed unless they are among a handful of state-owned enterprises and large petrochemical concerns. Not that operating as a solutions provider is easy. However, venturing into this space does offer the opportunity to differentiate and respond more specifically to the unmet needs of the customer. Fortunately, the technologies of the DME mean that operating as an asset-light solutions provider is becoming less cumbersome.

While extremely capital asset-light chemical companies are likely to become a greater presence in the industry in the near future, being asset-light does not mean that the industry's value will be eroded. Historical eight-to-twelve year innovation cycles could shorten, given that the time-intensive processes of material and processing technology could be accelerated by the use of digital tools. Given over a century-and-a-half of product and processing technology innovations, modern digital technologies can analyze and evaluate many chemical and material combinations in short time to come out with feasible new products and solutions. This, coupled with an asset-light model, is feasible and that the new asset-light company would be able to use contract manufacturing through the traditional asset owners (Differentiated Commodities and Natural Owners), can add certainty to achieving the end goals of product development.

In essence, the industry is entering a phase where every chemical company should decide what it wants to be. They can be:

- **Material manufacturers:** This will not be an even playing field, as there will be the Natural Owners (with feedstock, asset, and balance-sheet advantages) and differentiated commodities companies, both of which will present challenges to the new incumbents.
- **Solutions provider;** These companies will change their approach to focus more on market needs, but this category could also include companies from the digital space.

Companies should try to see where they stand today on the chemical multiverse map. That is, they need to find their starting point, evaluate their current conditions, and understand with clarity where they want to head in the future, and then make the necessary strategic changes to put themselves on the path to lasting success.

While this paper may appear extremely comprehensive given the whole gamut of issues covered – from macroeconomic forces to new segments of chemical companies to evolving business models – an elaboration is the need of the hour. By digesting the information presented in this paper, chemical companies can not only get a detailed overview of what is happening in the chemical multiverse, but also how the future may unfold and affect their way of doing business.

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Endnotes

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34. Companies in this group are not constrained by financial resources since they generally hold large amounts of cash and have strong balance sheets. As a result, they can venture into any business of strategic interest to them and can invest in programs (R&D or otherwise) which have long-term potential. These companies are also highly proficient in operational performance and can build scale and capacity in any segment of their choice. There are only a few constraints these large disruptors face, such as a shortage of skilled talent to address end-use market needs, managing expectations of their shareholders (e.g., government), and unwilling sellers and regulators.

35. Deloitte Development LLC observation, May 2017.

36. It remains to be seen whether the competitive advantage of the integrated manufacturer will win out in the fullness of time. However, at present, the trend is to move away from this model—especially for companies relying heavily on the capital markets. Hence, the once 'superpower' status of historic and well-known 'Strategic Leaders' is challenged. In fact, it appears as though the mission of a strategic leader these days is to remain a strategic leader and to move up and to the right on the map (i.e. better returns and greater resources for growth). This is not an easy task in a time when public companies have been under the scrutiny of activist shareholders and corporate boards have very low tolerance for underperformance. They also face greater levels of public and government intervention for non-compliance with environmental, public safety, or regulatory issues. In addition, the rise of social media puts public perception and consumers' opinions in the spotlight in real time. 'Strategic Leaders' are remarkable companies with profound accomplishments and legacies.

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