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Aim and Scope

The Journal of Business Chemistry (JoBC) focusses on current developments and insights at the intersection of management and chemistry, biotechnology or pharmacy.
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Letter from the Editors

The macroeconomic sky is cloudy

The economic outlook for the upcoming quarters is rather shaky. As a supplier to almost any other industry, the chemical industry is negatively impacted by recessionary trends . A shrinking demand of the global manufacturing industry for instance, severely affects the chemical industry due to the intense supplier-customer relationship. As a result of the negative business climate and falling demand expectations, industry investments of chemical companies are in a slowdown at the moment. Currently, global markets face a lot of uncertainties. The Eurozone is weak, Germany is maybe close to enter a recession, the Brexit is still unresolved, the trade war between China and the USA, and last but not least the recent escalation at the Persian Gulf. Furthermore, the condition of the chemical or process industry, in general, seems to be very unstable. Bayer is still suffering from the Monsanto takeover. Covestro lost almost half of its value from 2018, and the BASF is facing various problems, with operating profits expected to fall by up to 30 percent in 2019. More than ever, chemical companies are asked to cope with emerging challenges. Thus, the Journal of Business Chemistry intends to provide some guidance for our readers in opaque times.

In “A pulse on the specialty chemical sector”, Owen P. Jappen compares projections from economic experts for the effect of trade of short-term factors and contextualizes projected megatrends which might affect the specialty chemical industry. He concludes that chemical companies should be agile and diversified across a range of chemistries.

Almost 20 years after the dot-com bubble, B2B electronic marketplaces are again entering the chemical industry. Lars Schmitt collected in his article “Challenges affecting the adoption of B2B electronic marketplaces” challenges that electronic marketplaces in the chemical industry are currently encountering. After classifying these challenges into four categories, he proposes a conceptual framework that helps practitioners guide their strategic decisions.

Steven Peleman’s article “A holistic framework and development agenda for accelerated transition towards a sustainable chemical industry” deals with the full transformation from a linear to a circular economy and all associated consequences that come along with it. He proposes the concept of Molecules as a Service (MolasaS) which requires to overcome three big challenges: material identification, lifecycle counting in familiar ecosystems, and value for cycles. In order to finance such endeavors, he introduces a nested fund structure.

In the research paper “Commodity price fluctuations and the EROI of oil - How the availability of surplus energy affects non-fuel commodity prices” Johannes Lübbers and Karten Bredemeier investigate the long-term effect of a changing energy return on invest (EROI) of oil on non-fuel commodity prices. Their research shows that the EROI of oil explains up to 30% of commodity price index fluctuations.

Now, please enjoy reading the third issue of the sixteenth volume of the Journal of Business Chemistry. We are grateful for the support of all authors and reviewers for this new issue. If you have any comments or suggestions, please do not hesitate to contact us at contact@businesschemistry.org.

Thomas Koppel	Bernd Winters
(Executive Editor)	(Executive Editor)

Journal of Business Chemistry

Commentary

A pulse on the specialty chemical sector

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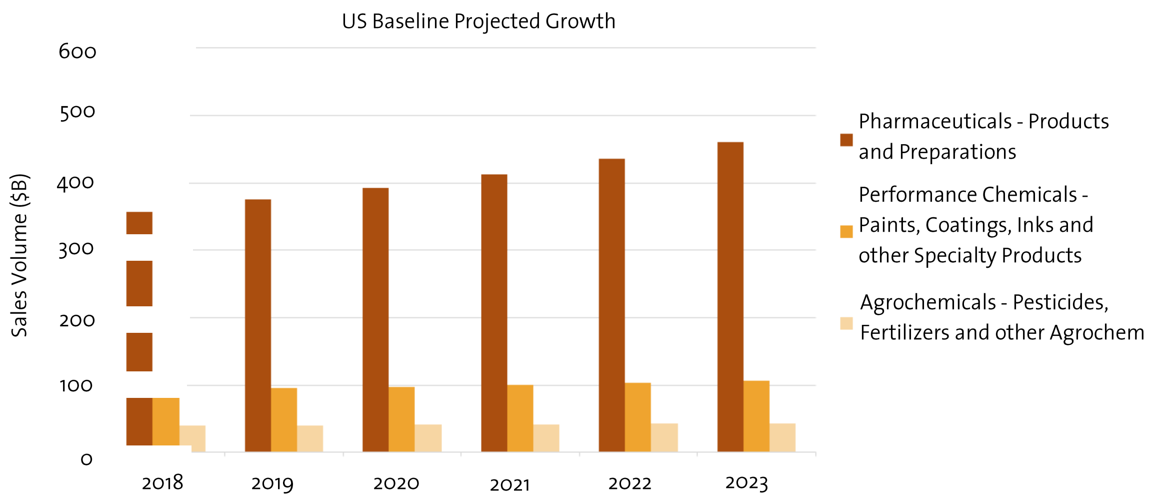
1 Introduction

When examining the chemical industry, it is important to differentiate between commodity chemicals – which are often manufactured via large-scale, bulk volumes – and specialty and fine chemicals – manufactured for customized applications and characteristics at much smaller volumes. Specialty and fine chemical manufacturers supply into industries across pharmaceutical, performance and agrochemical sectors accounting for up to $357B in the United States compared to circa $800B associated with the chemical industry overall. As a corollary of being rooted in smaller volumes, the specialty chemical landscape is composed of contract and custom manufacturers which can be more agile due to their diverse range of capabilities and find themselves better poised to react to trade disruptions to the global supply chain. The most impactful challenges facing these industries in the coming years will be more rooted in industry socio- and technical trends – such as sustainability, cyber security and digitalization – than global megatrends rippling through commodity chemical markets.

This paper compares projections from economic experts for the effect of trade of short-term factors and contextualizes projected megatrends and how the specialty chemical industry is best suited to weather them over the years. It furthermore discusses trends which may have a greater impact to business operations, such as a customer push for attention to sustainability, cyber security and digitalization.

Figure 1 US baseline projected growth (source: Draco, 2019).



2 Setting the stage in 2019 and beyond

The end of 2018 was characterized by a surge in purchasing for the specialty chemical industry, resulting from a stockpiling of inventory in preparation for tranches of tariffs in place for the US, Brexit, and offshore disruptions including environmental-based plant closures in China (Hirsh, 2019). The increase in inventory manifests itself with softer sales volumes, as manufacturers work through this material-on-hand. In spite of this phenomenon, capital investment in manufacturing facilities is expected to rise 2.2% over the next 12 months (Moutray, 2019), with 85% of those in the specialty and fine chemical sector planning some sort of capital expansion (SOCMA, 2019). While this may seem initially counter-intuitive, economic models project that the chemical industry will see growth in most all scenarios, albeit stinted from full potential.

The tendency of these key specialty chemical industry sectors to continue growth can be traced to chemistry's role in day-to-day life of society, it's relative independence from low-skill labor, and leadership in the realm of knowledge-intensive-value-add. Economic pressures may cause many companies to address long-term issues more expeditiously to take advantage of the potential for market share expansion. Just over four years out from the United Nations Sustainable Development Goals (SDGs), customer facing markets having become more sensitive to conveying their role in proactively advancing subsets of these goals. It is observable that these companies are working through areas for cutting their direct contributions to carbon emissions, climate action, life below the sea, etcetera. One can reasonably expect that they will next turn to their suppliers, and others upstream in the supply-chain, establishing a more holistic approach to tackling these goals. Some contract and custom manufacturers in the US have already noted requirements for sustainability appearing in their contracts. Global organizations, such as "Together for Sustainability" and "EcoVadis", are beginning to arise to address standardizing approaches to measure and certify these criterion.

Figure 2 Influencing factor projections (source: Draco, 2019).

3 Near-term horizon

The most frequently predicted influencers for the US economy in 2019 have been around a domestic recession, an escalation of trade tensions, or a stalling of the Chinese economy and thus, their global buying power. While none of these would result in a contraction for the specialty and fine chemical market, they do correspond with up to $30B loss in unrealized year-over-year revenue per influencing event, as compared with the projected sales volumes reviewed in section 2 of this report.

Conversely, the quick mitigation of these factors would enable some sectors to grow by an additional $5B annually in addition to already projected expansions. In a recent survey of specialty chemical industry executives, over 40% affirmed they believe a US economic recession is imminent and will impact their business growth, while only about one in ten believe that trade war tensions will continue to escalate past their current state.

Given the breadth of contract and custom manufacturers in the specialty chemical industry and the demographics' tendency toward batch processing, many facilities and companies stand able to take on repatriated volumes with little or no modifications to their systems. This agility mutes the impact of tariff/trade war induced revenue losses in comparison with an overall US economic recession, where capital investment would be tighter and could not accommodate any expansions or alterations made to facilities.

4 Long-term horizon

Looking forward for the specialty chemical industry, as in many sectors, artificial intelligence is identified as a major factor in altering the economics of manufacturing. Automated processes shift the levers of cost structure from wage-based to the cost of energy and quick and easy access to markets. When heavily implemented, artificial intelligence can be expected to encourage a sort of "regionalization" or "near-shoring", compared with the globalization that has been observed in the last decade. A recent report by the McKinsey Global Institute commissioned by the World Bank Group notes that the overall pace of growth for global chemical supply chains has slowed to 5.5% between 2007 and 2018, down from 7.8% between 1995 and 2007 (Lund et al., 2019).

Due to its cost-benefit advantage and the tendency of chemical industry leadership to utilize cost-cutting as the primary driver for profitability at a rate of 3:1 (Gotpagar et al., 2018), one could expect artificial intelligence technology to move ahead as one of the more prevalent long-term issues taken-up and addressed. An often unanticipated factor for company valuations during mergers and acquisitions is a company's consideration for sustainability. Anthesis Group, a global sustainability consultancy, notes that it is important to remember that "not every company can impact all 17 of the United Nations Sustainability Development Goals, but all businesses should identify which goals they do impact and how they have an opportunity to contribute to their achievement throughout the full value-chain of their business." In the contract and custom manufacturing space, it's becoming more and more common place to view this area of the supply-chain as something downstream companies face rather than part of a framework for performance and customer evaluation.

Along the digital front, a cross-industry and cross-sector issue often considered more to do with risk mitigation is cyber security. The risk and exposure to chemical manufacturers spans from operational and process disablement to intellectual property and should be assessed for mitigation via technological barriers as well as insurance policies to protect against financial windfalls. During a forum for executives in the specialty chemical sector in Houston in May, Laura Burke, Vice President of McGriff, Seibels and Williams, cited examples from Ukrainian based bank networks being taken down in under 45 seconds, to a 2014 operational attack on a steel mill in Germany resulting in process failure and equipment damage (Gaines, 2019). Specialty chemical business plans must take these issues seriously in order to stay competitive in the long-term.

5 A paradigm shift in supplier audits

Not only are sustainability requirements and cyber security measures being included in company valuations for MandA, but also in pre-engagement audits for specialty chemical contract and custom manufacturers across the US. A recent trade association report notes a dramatic increase in time spent on customer audits and preparing facilities to meet designated requirements – in many cases, even before discussing and finalizing contractual engagement. (Hirsh, 2019b). The increased rigor of these audits can present a business opportunity if specialty chemical contract and custom manufacturers are proactive in subscribing to a standardized sustainable audit framework. Assessments and audits which are conducted to a predefined set of criteria and shared across industry, improves efficiency for all involved (Unger, 2019). Similar to vertical integration and streamlining within specialty chemical companies themselves for shared services, companies could realize time and operational savings by agreeing to a common framework. Such a concept could be further utilized by chemical distributors and application enhanced by setting up centers and structures to bundle critical expertise and compliance with environmental and sustainability factors; identifying and sharing best practices and eventually applying KPIs to ensure continuous accurate assessment (Jung et al., 2018). Buy-in across the specialty chemical manufacturing landscape for common, transferable goals will assure it is aligned with its customer base and contribute to the general transformation of the industry to a more sustainable sector.

6 Summary

The nature of the specialty and fine chemical industry necessitates that it be agile and well diversified across a range of processes and specific chemistries. The traditional factors which delay the impact of overarching economic trends to the chemical industry give the sectors a chance to react and reposition themselves to weather disruption more smoothly than others for near-term events. By keeping a steady eye on key indicators, such as material sourcing issues, international trade tensions, and US-domestic recession signals, specialty and fine chemical manufacturers can strategically plan for their business operations.

Looking further to the future, cyber security topics to protect intellectual property, against ransomware and against general bad actors, must come into focus as a matter of good business practices. A changing consumer demographic must also be taken into account, with a heavier emphasis on sustainability, from energy consumption to product life-cycle. Current industry statistics show the majority of the specialty chemical industry is not well versed in this area, but this must change for future success.

Observed shifts with attention toward sustainability in public-facing-consumer markets can be expected to drift up the supply chain to specialty chemical manufacturers. Heeding these trends and subscribing to standardized frameworks for measuring and auditing these processes will lead to favorability in the marketplace and reduced operational costs, long term.

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Journal of Business Chemistry

Practitioner's Section

Challenges affecting the adoption of B2B electronic marketplaces

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Almost 20 years after the bursting of the dot-com bubble, we are again experiencing a boom in B2B electronic marketplaces. These marketplaces usually connect buyers and suppliers in the digital sphere; however, the implementation of a marketplace comes with numerous challenges in the B2B sector. Marketplace operators often reach their limits, especially at the operational level. Based on expert interviews with five electronic marketplaces from the chemical industry and from other data sources, we have collected these challenges and classified them into four categories: (1) Technical Level, (2) Individual and Cultural Level, (3) Corporate Level, and (4) Industry Level. The categories presented in this case study extend an existing research model that deals with the adoption of B2B electronic marketplaces. This theory development provides a deeper understanding of electronic marketplaces, which is important for both researchers and practitioners. The mastering of these challenges has a major influence on the adoption of the respective marketplace as well as on its success or failure.

1 Introduction

During the dot-com bubble period, internet-based companies received a lot of funding through high investments that later turned out to be extremely speculative (Day et al., 2003). The bubble was created between 1995 and 2000, shortly after which it burst and went down in history as one of the most legendary stock market crashes of all time (ibid.). During the dot-com boom, numerous B2B electronic marketplaces (EMs) were created, most of which disappeared from the market during the crash or a short time later. Companies such as Chemdex, Chematch, or ChemConnect were well-known B2B EMs in the chemical industry at that time (Tedeschi, 2001; Glick, 2001; Kane, 2002). Almost 20 years later, we are experiencing a new boom in this industry with companies such as CheMondis, Chemberry, GoBuyChem, KEMGO, and Asellion (CHEManager, 2019). While these "new" B2B EMs share commonalities, they also exhibit differences. All companies focus on the chemical industry and pursue a marketplace model that aims to bring together buyers and suppliers of chemical substances. This makes them competitors, as well as interesting objects of investigation. A crucial success factor for every EM operator is the adoption of the marketplace in its specific community or industry, which can be defined by the regular use of the marketplace through the respective user groups, who can be grouped into buyers and suppliers (Driedonks et al., 2005).

Coming back to the chemical industry, the marketplace model represents an innovation since aspects that are still perceived as new for this very traditional industry accompany this model. For instance, EMs achieve a certain transparency and comparability through their platform character (ideally many buyers and many suppliers). We are already interacting with this scenario from the B2C context when we make purchases privately on marketplaces such as Amazon, where we can compare products and prices from different manufacturers or retailers. In the B2B sector, this transparency does not yet exist in many industries. This also applies to the chemical industry, where prices for chemicals are usually negotiated between buyers and sellers.

In the course of digitalization, the importance of B2B EMs is again increasing, as many of the current activities focus on the customer or the (end-) user. From the point of view of the B2B buyer (e.g., a procurement manager), the aforementioned transparency would be a desirable development. From the supplier's point of view, however, EMs represent, in most cases, a threat to the established business. B2B EMs therefore pose different challenges regarding their adoption than B2C EMs. The latter have been investigated intensely in research, which is probably due to the success of Amazon (Alt and Zimmermann, 2019).

In this paper, we discuss the challenges of B2B EMs by applying the grounded theory approach formulated by Glaser and Strauss (1967) to the five chemical marketplaces mentioned above. With this research, we contribute to the field of digital business and e-commerce, and, more precisely, to the field of electronic marketplaces and their adoption. We will start by presenting the current state of the literature and explaining the methodology in detail. We will then introduce our case study, which contains the main challenges regarding the implementation of B2B EMs from the perspective of the marketplace operators, and discuss the extension of an existing scientific model from Driedonks et al. (2005) for the adoption of B2B marketplaces. Finally, we will conclude with the limitations of our study and the implications for future research.

2 Theoretical background

Electronic Marketplaces (EMs, also “Electronic Markets,” “E-Markets,” “E-Hubs”, “Two-sided platforms”) received a lot of attention from researchers at the time of the dotcom boom and the years that followed. Among several definitions that arose during that period, Archer and Gebauer (2002, p. 1 f.) describe EMs as “virtual marketplaces where buyers and suppliers meet to exchange information about prices and product and service offerings, to collaborate, and to negotiate and carry out business transactions.” EMs can also focus on the B2B sector by allowing business partners such as suppliers and buyers to communicate and conduct business transactions (Timmers, 1998; Chow et al., 2000).

The desire to categorize EMs has remained unbroken ever since, especially when closer attention is paid to the features and functions of an EM, where you can differentiate between exchange, auction, or aggregator (ibid.). Kaplan and Sawhney (2000) suggest categorizing B2B EMs according to their product portfolio and whether EMs perform correspondingly as horizontal or vertical markets. Others focus more on the dynamics and mechanisms inside an EM, e.g., by focusing on the aspect of competition on a platform (Kollmann, 2000; Holland, 2002; Belleflamme and Peitz, 2019), on pricing strategies and information transparency (Yoo et al. 2002; Soh et al. 2006; Zhu, 2004) or on the evolution of an EM (Tomak and Xia, 2002, Thuong, 2005).

Day et al. (2003, p. 132 f.) elaborate on the distinctions by regarding the functions as well: “These exchanges offer various combinations of six core services: (1) information exchange, (2) digital catalogues that help to automate the procurement process, (3) auctions that attract large numbers of suppliers to compete for contracts, (4) logistics services to facilitate the physical movement of goods, (5) collaborative planning so different members of a supply chain can view each others' inventory levels and production schedules, and (6) value-added services such as design collaboration, financing or offline brokering."

The pioneers of the research field might be Malone et al. (1987, p. 488), who said that EMs "electronically connect many different buyers and sellers through a central database." Shortly before the bursting of the dot-com bubble, Choudhury (1997) added that EMs are "inter-organizational systems through which multiple buyers and suppliers interact to accomplish one or more of the following market-making activities: (1) identifying potential trading partners, (2) selecting a specific partner, (3) executing the transaction." Another definition from Standing et al. (2006, p. 297) again focused more on the B2B sector: "In its simplest form a B2B e-marketplaces can be defined as an inter-organizational information system that allows the participating buyers and sellers in some market to exchange information about prices and product offerings. Indeed, e-marketplace structures are complex and vary considerably according to the market maker's business strategy."

Following these general definitions of EMs, we would like to point out the different research streams existing in this field of research, in order to make clear where our contribution lies. Standing et al. (2010) categorize the literature into the following categories and subcategories (see Table 1). One limitation noted by the authors is the focus on scientific journals located in the area of information systems. They only included one journal outside the field of information systems, which was Management Science.

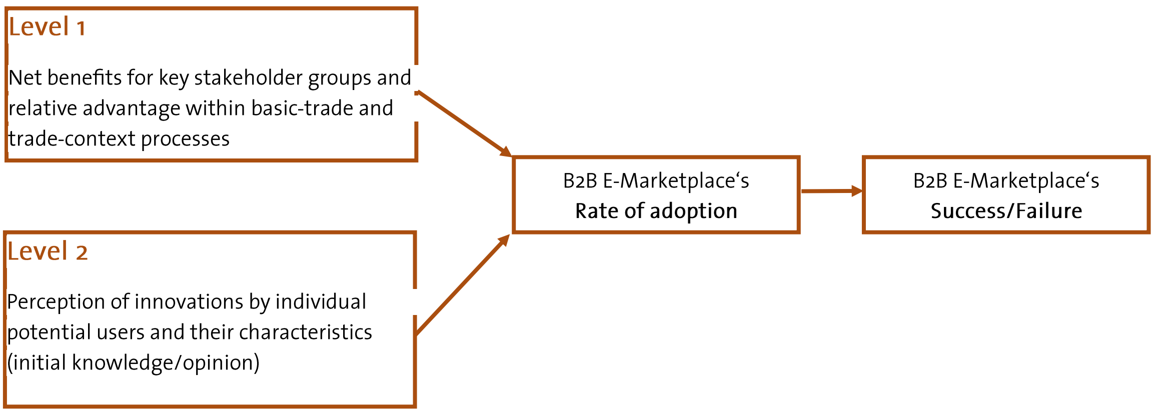
With our research, we mainly contribute to the research stream "adoption of (B2B) electronic marketplaces," where the key research question is: What affects the adoption of B2B EMs and how can the factors influence the possible success or failure of EMs? In other words, it is about the decision of the EM user to adopt the "new way of B2B trading" (Driedonks et al. 2005, p. 50). The research stream on the adoption of EMs is based on different theories like the technology adoption theories, such as diffusion of innovation theory and technology acceptance model, as well as on other theories, such as social network theory, transaction cost theory, or resource dependence theory (Bakos, 1997; Wang, 2008; Luomakoski, 2012). Driedonks et al. (2005) define the rate of adoption as "the relative speed with which an innovation is adopted by members of a social system, which is generally measured as the number of individuals who adopt a new idea in a specified period, such as each year." In this paper, we take the same position as these authors and understand adoption "as the range of behaviors from the decision to use an innovation to full and regular use of it, and rejection means the decision not to use the innovation at all" (Driedonks et al. 2005, p. 50 ff.). The success or failure of an EM is closely related to the rate of adoption, which was addressed strongly by researchers at a "high level" that is quite far away from the operational level that platform operators face in their daily business. For this reason, we focused on this operational level.

Driedonks et al. (2005) show this in a case study on the Australian beef industry, in which a marketplace emerged at the time of the study. They distinguish between two levels that influence the rate of adoption of an EM (see Figure 1), which will be the basis for our (extended) research model: Their Level 1 deals with the key stakeholders that should achieve a relative advantage by using the EM, always compared to existing (perhaps non-digital) transaction processes. Their Level 2 focuses on the actual user of the EM and, in particular, his or her (previous) knowledge and perception of the EM. Both levels or aspects have an influence on the adoption rate of the EM, from which it can be derived whether the EM will be a success or a failure.

Table 1 Research streams in the field of electronic marketplaces (source: Standing et al., 2010).

Category	Subcategory 1	Subcategory 2
Electronic Markets	General discussion	
	Efficiency	
	Pricing	
	Search costs	
	Product	
	Structure	
	Operational performance	
System	General system perspective	
	Auction	General
		Auction support systems
		Pricing
		Trust
		Auction types and strategies
		Revenue
		Procurement and supply chain
	Knowledge management systems	
	EM models	
	Trading mechanisms	
Adoption/Implementation	General adoption issues	
	Adoption approaches	
	Adoption in procurement and supply chain	
	Barriers/motivations	
Organizational issues	General organizational issues	
	Trust and security	
	Relationships and networks	
	Strategy	

Figure 1 Challenges influencing the adoption of EMs (source: Driedonks et al., 2005).



3 Methodology

The abductive approach describes a research process that mostly begins with “surprising facts” or “puzzles” that should be explained. These may emerge when a researcher encounters an empirical phenomenon that cannot entirely be explained by the existing range of theories (Saunders et al., 2012). In our study, the empirical phenomenon is the almost simultaneous emergence of B2B marketplaces in the chemical industry and whether they are adopted by their specific community or industry. Following this abductive approach, we propose a model that contains the main challenges regarding the implementation of B2B EMs from the perspective of the marketplace operator. The abductive approach can be viewed as a combination of deductive and inductive approaches. Deductive approaches deal with the development of propositions from current theory, which should be tested later in the real world (Yin, 2013). Inductive approaches rely on “grounded theory” (Glaser and Strauss, 1967), where theory is systematically generated from data. According to Glaser and Strauss (1967), there is a continuous iteration between empirical data collection and data analysis, which allows the generation of theory. In this paper, our research follows an inductive rather than a deductive approach, as we first dealt with data collection. At the same time, we were aware of current theory. After the data analysis, we were able to extend the model of Driedonks et al. (2005).

The main source of data are semi-structured expert interviews with company representatives (see Table 2). The objective of the interviews was to collect the main challenges of B2B EM operators in the chemical industry. In order to deal with a homogenous sample, only cases that follow a marketplace model in the chemical industry and are active in Europe were selected for this research. A total of eight interviews were conducted, in which ten experts from five companies were involved. These five companies represent around half of the population of chemical marketplaces that are active in the European market (Von Hoyningen-Huene, 2019). The interview partners were the CEOs, managing directors, or senior managers of the respective companies. The interviews took place on the phone or on site between January and August 2019. Each interview lasted between 30 and 60 minutes (total: ~5h). The interviews were transcribed and later analyzed with a focus towards the challenges of the platform operators expressed by the interview partners.

This resulted in four categories, which will be explained in the next section. Each challenge could be assigned to one of these categories. Secondary data was collected from company presentations, company websites, and newspaper articles. These sources mainly contained information about the participating companies (e.g., for the case descriptions) and about the industry in general as the context is quite relevant here. Additionally, we used newspaper articles for the introductory part (e.g., historical background). Due to the various data sources and the different companies involved, our paper follows a multiple case study approach.

4 Findings

In the course of the interviews, four different categories emerged into which the challenges of the EMs examined can be classified. We labeled these categories as follows: Technical Level, Individual and Cultural Level, Corporate Level, and Industry Level. We have assigned the respective challenges to these categories. Table 3 represents our main findings from the interviews.

The challenges of B2B EMs can be classified into four categories. At the technical level (1), there might be interface problems with existing and established systems that are already used internally (e.g., ERP, CRM). The manual upload of products to the EM or the updating of product information is also an additional effort.

Table 2 The five cases (source: own representation).

Company name	Founding year	Number of employees (09/2019)	Short description	Number of interviews/ number of interv. partners	Sources
Asellion B.V.	2019	24	Asellion is a private, reliable and scalable digital platform allowing suppliers of chemical materials to set up their own stores and sell their products directly to industry customers. This Software-as-a Service (SaaS) model has been designed with the future aim of hosting closed direct stores where sellers and buyers can transact in a flexible, private and secure way. The Covestro Direct Store is the first and currently only store on the platform, offering exclusive access to Covestro products and services to selected business customers. In the future Asellion will open up the platform to third parties and create more direct stores in addition to the Covestro one. The company is fully funded by venture capital from Covestro at the time of the interview.	1 / 2	Company website, Interview
Chemberry (Clariant International Ltd.)	2018	10	Chemberry is an internet platform enabling chemical buyers to easily find the ingredients they need. The company aims to be the most comprehensive source of ingredients available online. Detailed, up-to-date information and cross-referencing creates an intelligent search and compare platform for specialty chemical ingredients. The company is fully funded by venture capital from Clariant at the time of the interview.	1 / 1	Company website, Company presentation, Interview
CheMondis GmbH	2018	30	CheMondis is an online marketplace for chemical products. The start-up, founded by specialty chemicals group LANXESS, is designed as a B2B platform for companies to buy and sell products across all manufacturers and distributors. As a buyer it is possible to see the different suppliers on the platform, so CheMondis functions as a “matchmaker” between both sides (incl. payment options) but is not the contracting party. There are currently two ways to purchase a product through CheMondis: On the one hand in the form of a direct purchase option, if the supplier allows this, or on the other hand through an online negotiation.	4 / 5	Company website, Company presentation, Interviews

Table 2 (continued) The five cases (source: own representation).

Company name	Founding year	Number of employees (09/2019)	Short description	Number of interviews/ number of interv. Partners	Sources
GoBuyChem Ltd.	2017	4	GoBuyChem is an online marketplace for chemicals as well. Here, buyers can browse and choose products from different anonymized suppliers, so the buyers cannot see the different suppliers. Furthermore GoBuyChem is the contracting party, handling all logistics and transportation. In other words the company pursues a "one-stop-shop"- model. GoBuyChem is backed by private investors and business angels, as well as by the distributor Noahs Ark Chemicals.	1 / 1	Company website, Interview
Kemgo Inc.	2014	n.a.	Kemgo is a technology platform for different B2B e-commerce solutions. Their main focus is currently on an e-auctions marketplace for the chemical industry. This means that a supplier places an offer on the marketplace and various potential buyers can place their bids. Conversely, this is also the case so that different suppliers can apply for a request from a possible buyer. Kemgo was founded by two entrepreneurs.	1 / 1	Company website, Interview

The basic goal of EMs to accelerate the trade and make it more efficient can already fail at this level. At the individual and cultural level (2), it might become challenging as well: depending on the cultural area, there may be tendencies towards a higher or lower affinity with regard to the adoption of new technologies and innovations. In addition, humans seem to prefer established processes to unfamiliar and new processes. In terms of the work context, there is often a lack of incentives for an employee to take up the challenge of new digital solutions. If an employee suggests new (digital) processes, this can even be risky and, in the worst case scenario, can lead to bad team dynamics or related problems. For this reason, a bottom-up approach appears less likely than a top-down approach. Thus, managers need to approve the new technology/innovation before the operative staff is going to work with it.

The corporate level (3) also brings various challenges: If the transaction should take place on the EM, prices must be fixed or negotiated there. Fixed prices that are open and thus visible to the user of the platform pose a problem for many suppliers in the B2B sector. They are worried that price transparency will threaten the established business and that the potential customer will make their decision based only on price. In addition, there are various uncertainty factors. On the one hand, it is difficult for suppliers to predict how many new leads or customers can be generated through the EM. If many new requests arise, new employees might have to be hired to serve them. On the other hand, the behavior of the platform operator is difficult to predict. What exactly happens to the data generated on the EM and is it al-

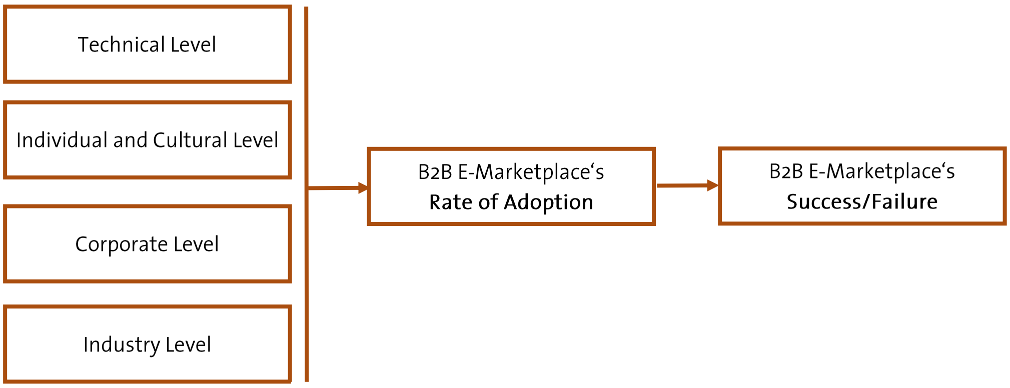
Table 3 Findings and categories (source: own representation).

Technical level			
1)	Missing interfaces between EMs and corporate systems (ERP, CRM etc.)	2)	Manual upload and updating of products/product descriptions
Individual and cultural level			
1)	Differences in cultures with a higher affinity for new technologies/innovations than others	3)	Usually there are no incentives for employees to work with new digital products
2)	General mindset of most people preferring established processes over "new way" to do something	4)	Sometimes it is even risky for the individual to break with the established way of "doing the job"
Corporate level			
1)	"Open" pricing becomes a major challenge for many corporates and is hardly feasible as lack of transparency is a fundamental component of B2B sales	4)	Liability – Who is the liable party? The platform operator or the seller behind the platform? Such questions arise when there are different business models, e.g. "Matchmaker" vs. "One-Stop -Shop"
2)	Uncertainty due to unknown platform dynamics (particularly problematic for suppliers on a marketplace: Will there be more orders? Do we have to hire new staff?)	5)	Selection of the "right" business model: Matchmaker (Problem: Once the platform connects buyer and supplier, they might leave the platform) or One-Stop-Shop (Problem: The platform becomes relatively powerful if the buyer does not know where the product comes from)
3)	Uncertainty due to operators' behavior that might not be clear or trustworthy for the platform participants (buyers/suppliers), especially when it comes to data protection and sensitive information		
Industry level			
1)	Industry might fear a high degree transparency that could damage the established business	3)	That relates to the fact that strong customer-supplier relationships are preferred in the B2B sector resulting in a relatively small spot market (that is most of the time targeted by the marketplaces)
2)	Supplier selection is usually a complex evaluation process, so it is not easy to enter a new business relationship "overnight" in most industries		

ways used to the advantage of all EM participants? Unresolved questions reduce the adoption rate, especially in the B2B area, where highly sensitive data is often involved. Furthermore, the question of liability and the appropriate business model arises. If the EM functions as a "matchmaker," the EM is openly bringing the demand and the supply side together, without necessarily being the contracting party. If the EM follows the model of a "one-stop-shop", the EM is the contracting party. Both the "Matchmaker Model" and the "One-Stop-Shop Model" have advantages and disadvantages for the EM operator as well as for the EM participants.

When it comes to the industry level (4), transparency about prices, products, and suppliers is particularly problematic for the supply side. This transparency is, at the same time, one of the core value propositions of an EM from the buyer's perspective. In traditionally oriented industries, such as the chemical industry, trans-

Figure 2 Extended model showing the challenges influencing the adoption of EMs (source: own representation).



parency-creating EMs therefore reach their limits. Another characteristic of B2B transactions in general is the pre-qualification and evaluation of suppliers. These processes are usually time-consuming and complex. EMs that focus on the transaction should therefore pay attention to industry-specific requirements. Another characteristic of the B2B sector is the general preference for strong firm-supplier-relationships. The so-called spot market for fast and unforeseen demand can therefore vary significantly in size from industry to industry. This raises the question of whether EMs always address the spot market or whether they generally try to cover the entire trading of an industry. The last aspect goes hand in hand with the hypothesis that all trade will take place digitally in the future.

5 Discussion and conclusion

Based on the study of Driedonks et al. (2005) and our findings, we propose an extension of their research model with the following steps: We suggest naming their Level 1 "Corporate Level" and their Level 2 "Individual and Cultural Level". We also suggest adding the "Technical Level" and the "Industry Level" to the model because these aspects are equally important but are yet to be treated. Our additions allow a broader view of the aspects that influence the adoption of a B2B EM and, consequently, also address a gap within this research stream. This is our contribution to the theory development (see Figure 2). Derived from the rate of adoption, a statement can be made about the success or failure of the respective EM.

6 Limitations and future research direction

There are limitations to the present study and the associated results. B2B EMs from the chemical industry may not, or only partially, be able to deduce B2B EMs in other industries. As far as our four categories are concerned, the classification of the findings is not always possible as there are overlaps between the categories. An interesting research approach would be, on the one hand, a process study that covers the development of B2B EMs over time, e.g., with regard to the number of participants or the possible revenue streams. On the other hand, in this study we have dealt intensively with the challenges that the platform operators are trying to solve with various activities. Another possibility for future research would therefore be to counter the challenges with the possible solutions . Since the field of EMs is regarded as very interdisciplinary, the literature categories and subcategories mentioned at the beginning of the paper can certainly be further developed. With regard to the economic effect of B2B EMs, it might also be interesting to examine their impact on an industry in general (e.g., patent applications, network effects). Assuming that B2B EMs simplify and accelerate access to new materials and products, EMs could have an impact on an industry's ability to innovate.

7 Implication for practitioners

Managers and entrepreneurs in the process of establishing (or planning to establish) a B2B electronic marketplace face various challenges. A profound analysis needs to be carried out during (or ideally before) the implementation of such platform activities. The levels mentioned above can serve as a guideline for this analysis. Each level should be dealt with intensively, for example, through methods such as customer and user interviews, stakeholder analysis, resource analysis, or ecosystem mapping. Based on the collected insights, a decision should then be made about whether and in what form a marketplace could be suitable for the respective industry. In most industries, there are already numerous highly specialized actors performing the key functions of the potential new marketplace (e.g., product catalogues, brokerage services, logistics services, financial services). The aim of the possible EM should be to aggregate these numerous offers and services and to provide them to the demand side from a single source.

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Practitioner's Section

A holistic framework and development agenda for accelerated transition towards a sustainable chemical industry

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The chemical industry is one of the biggest and most impactful sectors in society. Apart from its economic importance in terms of revenue and employment (CEFIC, 2018), it also plays a crucial role in the way mankind uses renewable and non-renewable resources now and in the future. Climate change, biodiversity challenges and waste pollution can only truly be tackled with the chemical industry as a partner. This means that the industry itself has to transition away from old and sometimes obsolete paradigms and ways of working. This paper suggests where and how to situate this change and presents essential mechanisms and concepts to help realize that change. The solution framework encompasses insights in environmental economics, new financial and non-financial valuation rules, different and more holistic leadership styles and specific technical levers. The aim is to trigger the reader's curiosity to find out more about the aforementioned ingredients and to launch a call to action to start exploring and experimenting. The time is now (Webster, 2017).

1 The origin of environmental economics

Environmental economics looks at how economic activity and policy affect the environment in which we live. As we all know, both production and consumption can have negative effects on our environment. Energy intensive industries can be the cause of a variety of emissions and increasing consumption in households often leads to the rise of either incineration or waste pollution in our local or global ecosystems (Hanley et al., 2013).

All this is true, but not necessarily inevitable. In fact, it is a consequence of linear thinking and/or a very narrow point of view. Our contemporary economic system favors maximizing top or bottom line growth within each step of the value chain, but not across the entire value chain. In essence, the bulk of our economy is therefore focused on a zero-sum game. Whatever benefits one is usually at the cost of another. Even though this is the predominant economic paradigm, also this is not per se inevitable.

Today however, it seems that countering these negative effects or externalities as they are called in macro-economics, can only be done by incurring a fair amount of cost. Costs for control, costs for cleaner solutions and of course costs for clean-up. Perhaps this is more of a philosophical statement, but we cannot deny that probably our economic calculus was inaccurate up until now. Surely, the true societal cost of any activity is much more encompassing than the 'naked' economic cost defined by only those actors involved in its supply and demand (Decoster et al., 2013). Moreover, just as in science where each significant breakthrough or challenge has an ethical dimension that needs to be considered, we are seeing at least a growing awareness of completing the economic equations with additional factors (Schwab, 2016).

It would be far too easy to blame economists all over the world for this twist of fate. Back in 1915 Cambridge economist A. Pigou already suggested taxation to control the above mentioned externalities. Pigou realized that given normal market dynamics the true societal cost would not be taken into account.

In economic terms, this is called a market failure and it cannot be overcome unless we allow some form of public intervention and regulatory control. How, to which degree and at what local to supra-national level is the real question. Evidently, our environment doesn't care about state borders, but policy making does play at different levels. In economics, the imperfections in decision making due to other and perhaps less rational or more individualistic elements are often referred to as bounded rationality.

Environmental economics provides a framework to craft a more subtle approach in which these known deficiencies are remedied. Nevertheless, it will be up to consumers, politicians and business leaders to stand up against the dominant logic of short-term financial pressure and zero-sum competition at all cost. In what follows, we will touch upon a few ingredients that could be part of the solution going forward. Win-win game theory, option valuation, system dynamics and complexity thinking, open innovation, venture financing, hybrid chemistries are just some of these concepts.

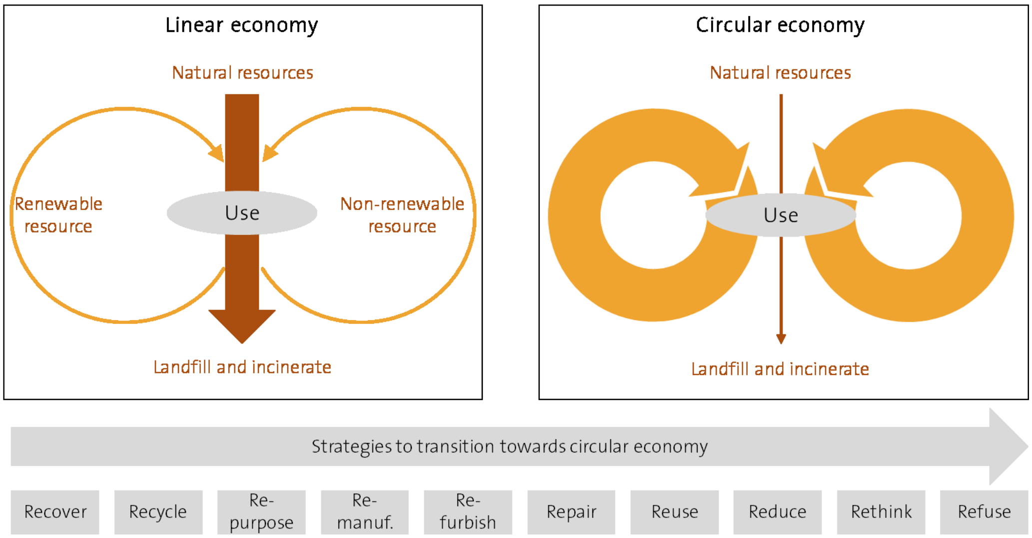
As I am writing this article today roughly 300,000 people - mostly students - are marching the streets of Australia, demanding more action to counter climate change and waste pollution. Many more marches have been planned and the intensity of these global protests seems to rise. In the late '70's and '80's I remember growing up with Greenpeace's slogan 'NO TIME TO WASTE'. I believe they were right back then, but we cannot go back in time. We can and must find positive and balanced (people – planet – profit) answers to the obvious challenges. In a rational and creative way, with confidence and optimism. If we fear we cannot change the ways of our global economy just look at a recent initiative by Vertis Environmental Finance, launching a contemporary performance indicator: WMKP or Would My Kid Be Proud (Atkins, 2019). Each decision is subject to the question whether that decision would make your children proud. Despite the dominance of financial metrics, the mere suggestion of a more emotional performance metric tends to trigger at least part of the executive legion.
As we will be focusing on heavy industries and the chemical industry in particular, I strongly believe that despite the past and perhaps part of the public opinion, they will be part of the solution. They have to be.

2 Clarity on how sustainability, linear and circular economy are related

Public opinion matters and publicity for the topic of sustainable chemistry and the circular economy is a good thing. This being said, it is also important to be precise enough and add some quality to these hot topic discussions. Quite similar to the Six Sigma and lean manufacturing hypes around 2000 and the explosion of innovation consultants right after – often enough the same 'experts' by the way – we are seeing a lot of sustainability and circular economy experts popping up. There is of course plenty of work to be done, but we are completely missing the point if we throw sustainability and circular economy on one big pile. The two topics are quite clearly related, but there are important differences.

Figure 1 tries to explain the difference in flows between a linear and circular economy in terms of how resources are (re)used and or terminated as waste. It is not so much about definitions or semantics. It is about what we see

Figure 1 Differences in resource flows between a linear and circular economy (source: Deloitte Point of View, 2019).



happening in terms of implementation efforts. Sustainability should take into account all 3 of its fundamental dimensions: economy, ecology and the social aspect. Quite often, the focus lies only on 'more green' or 'more resource efficient' because of the cost reduction potential. Two or all three dimensions are rarely combined. In that sense, sustainability is usually working on the 'more or less' side of things.

Nothing wrong with becoming more efficient and less polluting of course! The danger is that things don't fundamentally change and needless to say there is always an upper limit to how far you can stretch efficiency.

We explicitly wish to support a radical rethinking of existing models, processes, value chains and technologies to take matters way beyond the borders of compliance. Compliance in itself is a precondition. The true question is what the standard for compliance needs to be. Quite often we gradually and unfortunately stretch the boundaries of what production and consumption needs to comply to as it is based upon negotiation between various stakeholders including conservative forces (Heene et al., 2016).

In that sense, good is indeed the enemy of great (Collins, 2001). On top of this, new opportunistic pools of business for service providers blur more existential decisions. Take digitization as an example. Digital is an important driver of change in the chemical industry and it will influence the way in which businesses or operations are managed. However, digital can assist in dematerializing the sector but its essence remains quite physical. Therefore, we should not forget the opportunities of making chemicals more sustainable or circular outside of the digital portfolio. If we were to assemble the digitization wave and the efforts into sustainable chemistry in one big container concept called Industry 4.0 or Chemistry 4.0, we must be honest in what this means (Deloitte and VCI, 2017). The alliance to fight plastic waste pollution had initially pooled one billion whereas an ERP software update for one of the major chemicals players amounts to 1.6 billion.

Becoming more circular forces us to rethink everything. From existing practices to shared governance and serving leadership, reverse logistics, open ecosystems, away from certain economies of scale and towards increased diversity and complexity.

It all sounds quite troublesome to become circular at first, but the contrary is true. If certain fundamentals are reconsidered, a lot of value can be unlocked as well. Plastics engineers all know the phenomenon of fountain flow and shearing. Let us use this phenomenon to explain a potential effect of circularity. In a planar market place, a linear approach will 'hit' a part of the market but given the zero-sum game it will also push aside a lot of market potential to either side of the linear force which could be thought of as an arrow (Strogatz, 1994). We will explain the concepts of zero-sum and zero-plus game below, but for now just think of the same planar market space in which a number of organizations have set up a circular value chain based upon a win-win payback for all involved and hence a zero-plus game for this ecosystem (Davis, 1983). This rotational force – so not an arrow – can based upon its negotiated stability and sustainable character be seen as a mechanism that sucks into the circle more and more market space. In system dynamics and complexity theory this phenomenon is also known as a virtuous cycle, as opposed to a vicious cycle (von Bertalanffy, 1969). It is not unlike a black hole in astrophysics, although a lot less hostile as an environment, quite the contrary (Hawking, 2001). Perhaps this is the utmost important remark about circularity. It is not necessarily about physical material rotating in a perfect circle. It is about circular value chains with maximum material circularity that attract adjacent cycles and market potential into its equilibrium. Mathematicians will undoubtedly make the link with fractal geometries and the precipitation principle is indeed similar in logic to what a circular economy could instigate (Mandelbrot, 1977).

3 Contemporary leadership and governance for a fertile soil

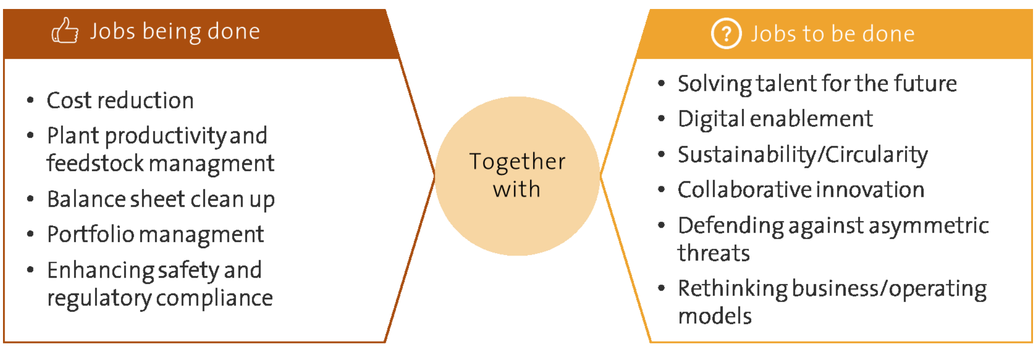
What to focus on is a leadership choice. Choices depend upon leadership style and vision. Hence, perhaps even more important than specific frameworks or knowledge is the difference in leadership style and decision making going forward. Blame, panic, negativity and opposition will not get us any closer to a fast-paced moving target. Chemicals executives must accept that most if not all of the old decision criteria remain part of the existing corporate dashboard. The way in which these targets in addition to new ones have to be realized however, is entirely different.

In 2019 Deloitte summarized this dichotomy as follows in Figure 2.

Interestingly, when talking to former C-level executives very few professionals consider this as something new. Quite often they mention that this balanced approach or mindset that should have been there all along.

To them, it is clear that the dominant dy-

Figure 2 A mandatory shift in focus for chemical industry leaders (source: Deloitte Point of View, 2019).



namics of short-term financials have skewed the relationship between old and new, between ratio and creativity, between linear and complex. At the same time and after some introspection, it is also clear that it has been very hard to stand up against this unbalance unless committing career suicide. This is why we are still seeing more efforts put into debottlenecking old production facilities or upgrading ERP releases than experiments using the existing asset base with new forms of for instance hybrid chemistries or partial bio-based feedstock streams.

Luckily, there are some quick fix solutions to overcome this unbalance. I suggest the following:

3.1 Ambidextrous leadership and thinking

Athletes and coaches have been investing in the ambidextrous mind for some time now. The cognitive performance in sports, arts but also in education and of course in business management benefits from a balance between an optimally functioning left AND right side of the brain. Additionally, the link between both hemispheres is equally important. Whereas in sports, significant progress can be made by improving the peripheral sight resulting in more accurate movements, a healthy balance between strong analytical and creative skills results in a much broader range of options. Quite often, these extra dimensions of creative, intuitive and emotional intelligence allow leaders to stand out from the vast majority of mere managers. What's more, these options become part of an automatic toolkit that can be called upon almost instantaneously. This stimulates a truly learning organization (Morgan, 1998 and Senghe, 2006).

When choosing our leaders, we should pay attention not only to go for the obvious profile using all the buzzwords and standard track-record. Instead, we also need to search for proof of creativity, an open mind and an affinity to deal with complexity and conceptual challenges. Also for creative thinking and cognitive learning, there are many training programs.

3.2 Diversity

Decision making in chemicals is quite predictable when observed from a distance. It is a small world in which many very specialized experts and executives know each other. The available options for almost any corporate event or situation seem to be known as if listed in the Big Book of Running a Chemicals Business. In fact, proposing something outside of that list could be deemed outrageous and irresponsible! The only way to change this is to bring in new and 'unspoiled' voices. In recent history and rightfully so, we have seen a number of initiatives focused on increasing diversity to enhance gender equality, break down racial impediments and overcome religious or sexual prejudice. What is missing somehow is an effort to allow divergent thinking, which might well be the mother of all diversity acceptance. Boardrooms and shareholders need to get accustomed to 'difficult' conversations with people who don't necessarily talk the same language or are predestined to converge to known solutions. In that sense, why not use the medieval approach of teaming an experienced executive up with a creative youngster. Unlike the paternalistic oyabun - kobun relationships in a Japanese management culture that refers to parent – child like relationships based upon protection and loyalty, these junior – senior tandems actually try to harvest the best of both worlds, creativity from one side and experience from the other. Another mechanism is to install a fair degree of functional rotation within the senior ranks or to set a minimum number of different industries in the joint background at the boardroom table (and cascaded downwards).

3.3 Nested goal setting

Perhaps the easiest quick fix is to embed short to mid-term goals in a longer view envelope that forces decision making to take into account effect in the long run. By visualizing these potential consequences, it will also be easier to explain to stakeholders why evident but wrong decisions were not taken or were taken in a more nuanced way. As in mathematics, a local extremum is not necessarily the best outcome.

The principle of overarching targets is not new. It is also a mechanism to support collaboration across teams in cross-functional processes where otherwise internal competition could prevail. Obviously, the hardest part is to come up with meaningful longer-term goals (Key Performance and Key Result Indicators), but just translating the UN Sustainable Development Goals and what Europe has set out as targets for the chemicals (and in particular plastics) industry points us in the right direction.

Keep in mind that the younger generation won't look surprised when these targets come into play. Contrary to that, not having a long-term sustainable perspective might cause young talent to forego working in your company.

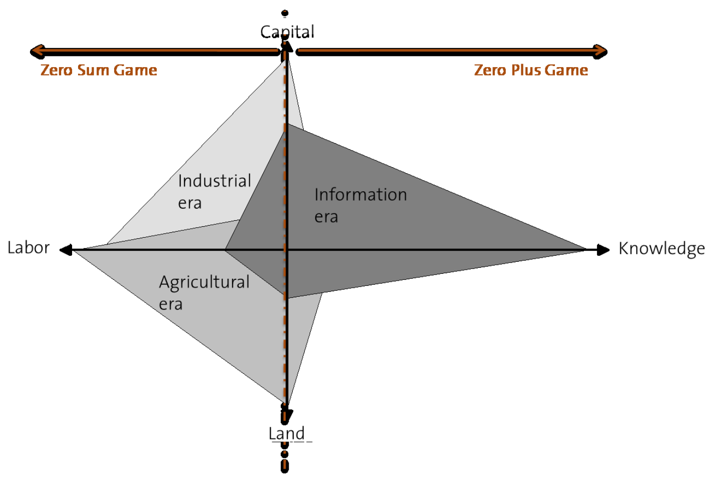
4 True sustainability in a world with scarce resources requires a zero-plus mindset

People Planet Profits (3P) and the zero-plus game are deceivingly simple concepts. I suggest using an analogy from a few years ago to explain the latter economic concept. The illustration below was created roughly 20 years ago when knowledge management became somewhat of a hype (Figure 3). Of course, nowadays we all see value in (big) data, but it was in fact the first time that economic production factors were shared to increase the overall economic value and not necessarily at the cost of another economic actor.

Simply put, the land, capital and labor you use to create your economic value can no longer be used by anyone else, whereas data or knowledge can be multiplied in its use as an economic production factor. It is fair to state that the old paradigm 'knowledge is power' is in fact not entirely true from an overall point of view. 'Knowledge sharing' on the other hand does maximize value creation.

The analogy is not quite perfect, but one can

Figure 3 Unilateral versus shared sublimation of production factors (source: Gorey and Dorat, 1996; Bueno, 1998).



feel the philosophy behind. Our environment, rare earth materials and non-renewable goods are typically production factors that should be treated in such a way that they shouldn't be held hostage to a single use by a single actor.

In terms of value creation and maximizing beneficial economic outcome, the overall equation is to stop harming our environment in any and every way, hence reducing the loss of societal wealth and economic wealth in the long run (Stahel, 2019; Pauli, 2017). Of course, we can only but dream of turning the situation around and finding ways to create a positive vortex, i.e. a virtuous cycle that draws in proper use of resources to generate sustainable outcomes. We will now dive into a few pragmatic approaches and ideas to remedy the current situation.

5 Introducing Molecules as a Service (MolasaS) as a catalyst for circular valuation

How does one find a way to change the linear relationship between supply and demand, between one and the next cog in the value chain of a product or service? At least it should be as lucrative as before or the 3P scenario is off the table. That is what is currently blocking a lot of corporate initiatives. Environmentally safer solutions come at a cost and their business case seems to be less interesting. That is true, but only in part. It is true if we cannot expand our mental horizon beyond changing one or a few elements in the existing equation. It is not necessarily true if we change the equation altogether. A second hurdle is the linear horizon. If we find a way to rethink the equation, it is also key to review the pay-offs of all stakeholders involved. We need to look for beneficial linear relationships as well as an overall win-win situation. Earlier on, I already mentioned the virtuous cycle that attracts new and better business volumes. The stability and clear optimum for all is far more difficult to prove in the short run however. In what follows we will try to give a practical example of how this could work. For the interested reader who would like to learn more about the frameworks behind, I kindly refer to the work of people like Axelrod and Nash on game theory and economic equilibria. This theory explains the basic idea when economic actors are faced with different strategic options and how to maximize pay-offs given the choice of a strategic 'opponent'. The pay-off for both depends on mutual decisions that are however unknown to each other. The so-called prisoner dilemma is probably the most famous example of such a 'game' and it revolves around asymmetric information. In the Axelrod experiment, the game is repetitive and both actors take decisions based upon their pay-off and eventually the pattern that arises from a combination of pay-offs and behavior, i.e. the choices made by all involved and how this evolves towards an equilibrium. Setting up a circular value chain holds many elements and challenges quite similar to this.

Let us turn to more managerial language. Changing the way we do business is often referred to as changing an organization's business model. For instance, if a company is rewarded for the amount of physical goods it mines or produces, why would it change its way of working at the risk of losing shareholder value and damaging the careers of those in charge? It would not happen unless another way of value creation or value calculus were available. This is the point at which I would like to introduce the concept of Molecules as a Service (MolasaS).

Let us take the example of a chemical or petrochemical company drilling for oil or producing large volumes of chemicals. The economic reward, given the supply and demand balance, is based upon output volumes that are being sold to the market. Let us assume we leave inventory build-up aside for now. Let us also assume that all produced volumes are sold. This is not unrealistic if we look at crude oil and for instance MDI polyurethanes as our industries of choice (Randall et al., 2002).

Producing less volume means a direct hit on top-line revenues and because of we are dealing with asset heavy industries there might also be bottom-line effects. From a management point of view, the task at hand is clear. Regardless whether these organizations are triggered by top-line rather than bottom-line growth, volumes obviously must be replaced by a value increase in any other way. As we are dealing with the core of a business, a simple efficiency drill won't structurally improve matters. So, dreadfully sorry for the operational and commercial excellence consultants, but the game itself needs to be changed. I see three big challenges:

5.1 Material identification

Suppose we found a way to identify material batches, even up to molecular level, that allow material tracking and tracing over a number of life cycles. The idea seems crazy at first, but in fact it is not that strange. We naturally do not wish to change material characteristics in an unfavorable way, but the use of certain bio-markers could come in handy. In fact, I am currently working on a solution to do this with the help of a few cross-discipline experts. If the concept is strong enough, we will succeed in finding a technical solution. It is no secret that material characterization is a very strong scientific playing field and supported by biochemistry, forensic and tribology skills, we can come very close to crafting molecular DNA-like identifiers. Of course, for the sake of the argument we are oversimplifying things, but even without diving into nanotechnology and more emerging scientific areas, the reader must feel inclined to believe that identification of molecules will be possible at one point. Other practicality objections can also be overcome. For example, what happens if material is burnt or degraded, etc... Well, when sustainable chemistry, circular economy and responsible use of our planet's resources are the true drivers of our actions in MolasaS, we surely won't keep on throwing away or burning all of the energetic value that is still in materials after its first or second use or lifecycle. Hence we will have to come up with recycling and upcycling ecosystems that make identification of materials worthwhile. This is where challenge 2 comes in.

5.2 Lifecycle counting in familiar ecosystems

When and where would we count the presence of materials in a value chain? Perhaps we can learn from the royalty system in the music industry, but that is not a flawless system and it has side effects we wish to 'design out' right from the start. For safety reasons (the redundancy principle), let us track materials as they leave one partner in the value chain and go to a next partner. This way we have proof of material transfer from 2 sides of a single transaction. Let us also keep in mind that we are moving in the direction of much more controlled value chains anyway. This is partly due to the fact that circular value chains are in need of full transparency certainly in its initial stages, but also to upcoming and ever more detailed requirements around end-of-life as in Extended Producer Responsibility (EPR) schemes. EPR is an environmental protection strategy to reach an environmental objective of a decreased total environmental impact of a product, by making the manufacturer of the product responsible for the entire life-cycle of the product and especially for the take-back, recycling and final disposal (Lindhqvist, 1992).

In short, transactions and physical flows are becoming more transparent, which in turn also allows for circular value chains – or ecosystems – to reduce volatility of supply, quality and payoffs over a continued relationship (so far less one-off transactions similar to Axelrod's 'tit-for-tat' experiment). Readers from the chemical industry will acknowledge the value of having less volatility in its system.

Without diving into the technical complexities of identifying product material's origin - call it a sort of 'appellation d'origine controllée' similar to wine estates – we must realize that all players in the value chain will have to play ball. EPR rightfully places more responsibility into the hands of material OEM's or product OEM's, but we will have to include the participation of waste collectors, recyclers, B2B intermediates and even end consumers somehow (McDonough and Braungart 2013; Hawken et al., 2010; Lacy and Rutqvist, 2015). No doubt pilot cases will have to start small, but decent overviews of such ecosystems do exist. In Belgium for instance, industrial packaging waste and B2B waste in general is managed separately from public consumer waste by the organizations Fostplus and Valipac. They have a very thorough insight into who does what with which volumes and with which discrete material flows.

In terms of how cycles of use have to be counted, it seems that blockchain offers the right mix of big data capacity, real-time performance and global monitoring potential (Tapscott et al., 2016). Examples of tracking and tracing vast logistics flows are available, so also this second challenge can be considered 'achievable'. This brings us to perhaps the most difficult challenge, as it is not a technical challenge, but demands a new way of working, a behavioral change in how our economic valuation system works.

5.3 Value for Cycles

We are now at the point that we can create or tag materials with unique identifiers that allow material flows to be traced along more than one lifecycle, even if these materials undergo some transformation through recycling, upcycling and/or remanufacturing processes. Knowing full well mechanical and chemical recycling are quite different, there is no reason not to assume that even in the case the original material changes radically, also this transformation can be identified for traceability purposes somehow. And even if we were to limit this thought experiment to very simple pilot cases, the logic and consequential societal benefits are still valid.

So, at each step we have been able to register these transitions and we can therefore count how many lifecycles molecules have had in our physical world and in our economic system. The following question is as evident as it is difficult to answer: who gets paid what and at which point? Remember that we need to replace the growth value otherwise generated by producing and selling more non-renewable goods. Carbon dividends, CO_2 emission certificates and even carbon dividends are all partial solutions of our awakening sustainable economy, but here we seem to be touching upon the very essence of our financial system. We have also seen that despite a near bankruptcy of that same system in the past global financial crisis, very little has changed and to say the least, it is a system that is powerful and influential in order to stay alive.

Without claiming to have the best and only solution, we feel that the core business of existing companies is improbable to transition first due to existing obligations. Rather, it will be up to new incumbents or non-core branches to come up with new and more daring business models.

Everything starts with not or only fractionally getting paid for new production and extending payments over a longer period of time with the frequency of lifecycles and the intrinsic value of materials and goods at that (re-)iteration point as main value drivers, on top of the normal market dynamics of supply and demand. Highly differentiated or unique offerings that are desired by B2B or B2C customers have to be offset by the discounted value over time of these iterations and transformation steps. Tricky business.

Nevertheless, we could think of the above mentioned controlled pilot ecosystems and *we could perhaps apply such valuation principles in a context where margins are low anyway (commodity materials) or in those areas were new production is impossible due to lack of* *availability or prohibited for instance because of inhumane labor conditions*. What is on the market already has a clear functional value and reuse or iterative cycles are only exposed to competition in light of substitution potential by better or more sustainable alternatives. That in itself is a positive economic driver towards more sustainable solutions.

How to value such scenarios is not straightforward, but we are seeing attempts to pilot in very specific areas. Also, on top of academia investigating how real options valuation and game theory can be used, big banks are also starting to explore what this could mean for them. At first in the form of risk mitigation, but pretty soon also for the discovery of new business potential.

There is no science behind, but as soon as traditional financial institutions start embracing these new valuation rules, we might really see a whole cascade of events and an acceleration of the new economy put in practice (Tol, 2019; Wind et al., 2004).

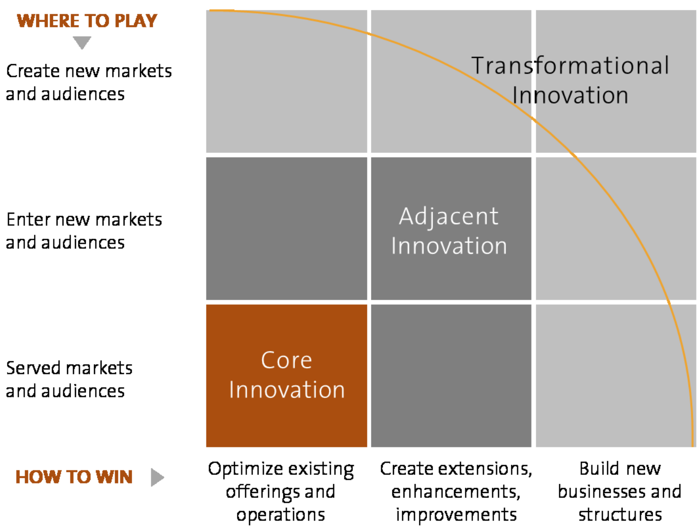
6 Venture logic and fund structures to run and finance circular disruptive portfolios

Mass demonstrations are a sign of the time and an emotional reaction to an underlying feeling of discomfort. Those economic actors capable of making a necessary transition more tangible should acknowledge this sign and act accordingly. We all know a status quo is causing harm to future generations and overall most economic actors are willing to change. The only question is how to move away from the current model. Similar to a black hole pulling in all matter and even light, our current dominant model leaves very little room to escape from. We also see this when reviewing companies' innovation portfolios.

Depending on sector and organization up to 70% or more of the innovation efforts are situated in the core or incremental innovation arena. Technology and market extensions in line with what exists in that core make up for the rest with very little room to experiment away from that 'envelope'.

Nevertheless, in challenging and highly un-

Figure 4 Deloitte's Where to play – How to win approach as a reframing of the conventional Ansoff matrix (source: Deloitte, 2019).



certain - one could say fluid – times, options for the future or future core business areas have to be created in the top right corner of Figure 4. Commercial organizations take the existing or near finished portfolio to customers typically with a short-term focus. This is a natural dynamic of supply and demand where given the role of sales organizations immediate questions ideally get immediate answers. Technology experts have another hurdle to overcome when leaving behind their comfort zone. Apart from sometimes having very little maneuvering room in terms of time horizon and budgets, they are experts at what they currently do and diving into totally new and unknown areas would mean they are no longer experts. For true scientists that is quite often an uneasy feeling that requires very sound leadership to balance out (Magretta, 2012; Lafley and Martin 2013).

A solution on the rise is the strategic marketing function that can work as a gear box or tooth rack between both worlds. However, even though this function has very little to do with the traditional 4P marketing or let alone with marketing communication only, also strategic marketing will be under time pressure and will have to fit into the overall risk profile the organization wishes to accept.

This is why we see a big advantage in organizing the work that needs to be done by a small but very particular task force, almost a guerilla task force: the venture team. We will briefly describe how this works, what the key principles are and how to finance it. The reader can then take these suggestions to his or her own organization, tailor and try out. At first as a protected experiment somewhat under the radar, later with more vocal and structural support (Vander Velpen, 2016).

6.1 Why? Different dynamics!

Core business is core for a reason. The timely manner in which business is conducted in this area has direct impact on the organization's P&L and of course on the reward of those conducting it. Launching initiatives in the domain of sustainable chemistry and more circular ways of organizing value chains, is for nearly all organizations new and to some extent exotic. Applying the same rules and principles of core business and for that matter running this with the same people simply does not work. Many organizations have tried to set up disruptive innovation cells or studios, but most of them have failed as they had maternal DNA and/or a corporate footprint right from their very birth.

The solution for this alienating way of doing business, the venturing way, is to build in enough independence and a specific form of governance that fosters entrepreneurship but with the backing of a large corporate to tap into. Things need to go fast, are not necessarily always polished, might upset some people, question certain crown jewels and have a much higher risk/reward profile. It implies operating at the borders of and beyond the comfort zone of what is known and reasonable. We all know the G.B. Shaw paraphrase that all progress must come from the unreasonable man. We suggest a small but hard hitting venture cell populated by only those who can and wish to make a difference, even if it jeopardizes their traditional career path. In the end, these teams are creating options on core business of the future. There are no expected ROI's or average targets to chase. Coming up with NPV's is pointless. Rather, use downside accounting principles: what does it cost to find out how big it can get! In short, when you start, please keep performance management, sales directors and operational excellence executives far away and sponsor at the highest level. Without commitment at the highest level this will not work, so it is paramount to get the CEO's support.

Also, as soon as things start to shape, bring in the performance, sales and operational excellence colleagues as coaches to scale up successful initiatives.

6.2 How it works

There are many ways to start up a venture cell, but the crucial elements are enough support, enough independence, the right mix of capabilities, the right mentality of the guerilla team and clear governance. The ideal corporate venturing accelerator – because this is basically what we are talking about – would take us too far to describe, but we can give a few rules of thumb:

- Use the dreams of your quite people: there's often a lot of malcontent technology aces and very experienced market facing professionals out there. They have plenty of ideas on what needs to happen to head into a new direction. It gives an enormous motivational boost if such a program and visible structure suddenly allows these specialist to voice their opinion and contribute to a new story. Mix this with known out-of-the-box thinkers and do not be afraid to also include semi-corporate profiles, even external ones, that have an entrepreneurial track record of making things happen.
- Create a separate legal structure: be bold enough to allow for daily management to be outside of the hands of those responsible for the core. Of course there needs to be alignment, but this can be done through the board and an advisory board. These structures cannot wait for the decision making slowness of the corporate environment.
- Reserve separate financing: project based financing, zero based budgeting is all good and well, but here we are in the area of venture logic. Work with a portfolio budget and allocate budgets according to business case pitching and portfolio roadmaps.
- Manage one overarching portfolio but in dual logic: the C-suites of the mother company or joint initiative must oversee a balance across the core and the venturing portfolio. Nevertheless they must treat the venture portfolio in a different way as discussed above. It has to complete what is missing but cannot get stuck in solving today's problems.
- Set a very ambitious target based upon a clear vision: this seems to be a semantic and philosophical requirement, but it might be the most important one of all. The venture team needs a clear vision, ideally from the CEO, what is a future and desired state for all. This allows thinking without prejudice or predefined boundaries on what projects could be part of the portfolio of the venture team. There's plenty of time and opportunity afterwards to align this with the overall company portfolio.

6.3 How to finance

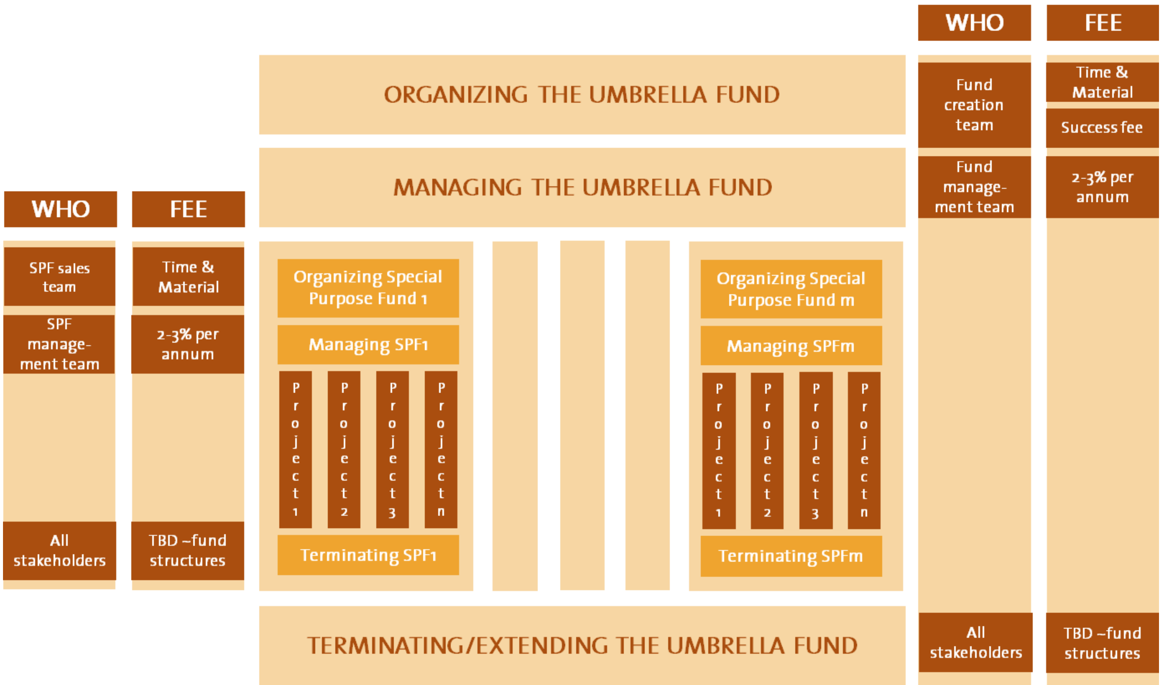
Organizations are sometimes struggling to find budgets for initiatives that are outside of the normal activities and structures. This is particularly true when the underlying initiatives were not known at the time these budgets had to be foreseen. Typically many of these disruptive ideas emerge unpredictably and by definition they miss the most recent budget cycle.

Nevertheless, there are lots of possibilities to provide oxygen to organizations and to finance projects, including the enormous subsidies made available by EU programs such as Life or Horizon 2020 (Deloitte, 2018), but we wish to suggest a mechanism that can scale up carbon neutral and sustainable chemistry investments at an entirely different level (Hudson, 2014; Tirole, 2006; van Peteghem and Mohout, 2018; Block and McMillan, 1993).

I suggest the following structure (Figure 5) that I will briefly explain as a way of introducing this channel:

I propose the creation of a nested fund, composed of an umbrella fund and several single company purpose or specific ecosystem purpose funds. As a side note, it is important to stress that the term fund is not necessarily a true fund in technical financial or legal terms,

Figure 5 Schematic of a nested fund detailing roles (WHO) and earnings (FEE) (source: own representation).



but it could be. The inner funds or SPF's in the nested structure will mostly be separate legal entities with a specific starting budget. Should they be big enough and/or populated by a few investing companies or for instance a specific circular value chain then a true fund structure is of course possible. Even the umbrella fund can take on different forms. If not a true fund, a foundation is a logical working structure. Nevertheless, technicalities taken aside the proposed structures have the following characteristics in relation to their nature and objective:

Umbrella Fund

- A leverage fund or foundation that can multiply the stakes and gets its rewards out of the IP, carbon credits and other benefits created by the underlying special purpose vehicle funds (SPF)
- ROI only comes when tapping into the resources of this fund
- Financial investors in this umbrella fund are carefully selected and must include a.o. 'patient capital' institutional investors and humanitarian influencers

Special Purpose Vehicle/Fund

- These funds can be organized as the venture portfolio extension of a specific company but also as a portfolio for a specific ecosystem as would be logical for circular economy endeavors
- The funds can for instance be financed by materializing corporate social responsibility (CSR) promises or can make use of revenues from CO_2 emission trading that are reinvested

With such a structure - and almost by design - all 3 P's can be part of the equation and sustainable innovation can foster. After all, there are plenty of technological developments at the verge of a breakthrough (Hawken et al., 2017).

7 Closing remarks

The chemical industry is a cornerstone of our economy and a driver of welfare and comfort in today's society. The sector also plays a vital role in moving away from old industrial habits and finding new solutions to the challenges at hand. Disregarding personal beliefs and emotional reactions, the chemical industry with its technology base, its processing power, its reach and its business impact must be part of a movement that seeks to face challenges in climate change, waste pollution and biodiversity. Based upon economic theory and management practice, it is equally evident that real breakthroughs will only take place given a radical rethinking of the current dominant linear model. In this paper, I have tried to outline a few basic principles and levers to do just that. Without being too specific for it to exclude one or the other sector or market, I have proposed different leadership style and mindset, subtle changes in our reward system, revised supply chains and material flows and a suggested roadmap to change valuation rules altogether. In an attempt to offer a very practical starting point, one that I am practicing on a daily basis, I have also described very briefly how to set up an innovation cell in venture fashion and how to finance it. I hereby welcome the reader to try out the above mentioned elements today. I also invite the reader to reach out whenever connections need to be established to get things done. To myself or to any other professional. We can turn things around in all prosperity!

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Research Paper

Commodity price fluctuations and the EROI of oil - How the availability of surplus energy affects non-fuel commodity prices

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We study the long-term effect of a changing energy return on investment (EROI) of oil on non- fuel commodity prices. Compared to economic growth, interest rates and uncertainty, the EROI of oil is the main driver of commodity price variations since 1938. A change in the EROI of oil accounts for up to 30% of the variation in commodity prices. We show that over the past 100 years, periods of low EROI have been correlated with higher commodity prices and vice versa. Commodity prices thus depend on the amount of surplus energy available for society. As renewables show substantially lower EROI values than fossil fuels used decades ago, the energy transition poses major challenges not only to our society but also to resource-intensive companies. The adoption of new business practices like the circular economy fosters the development of strategies increasing the EROI and reducing the large demand for external sources of energy and raw materials.

1 Introduction

Everything that happens in the world uses energy of one kind or another. Historically, the pre-agrarian hunter-gather era was characterized by an approximate energy balance where the energy each person derived from his food was almost the same which he expanded in finding that food. When humans started domesticating plants and animals more than 10,000 years ago, the agriculture revolution led to a liberation of surplus energy and the development of early societies. During that era, investment began when the energy surplus was deployed into the creation of capital goods instead of immediate consumption letting evolve simple shipping and trading industries (Morgan, 2013). The exploitation of fossil fuels during the industrial revolution vastly multiplied not only the energy availability but also the per capita use of energy. Due to the discovery of the heat engine it only took a little energy input to get a lot of energy out of fossil fuels, lifting ordinary citizens out of poverty into a developing middle class (Buchanan, 2019). Today, energy plays a major role throughout social and economic development and remains central to all politics.

However, it requires energy to produce energy. As the exploitation of any resource requires effort, to find it, gather it and process it into useful forms, it is not just the energy produced what matters most, but the relation between the energy that is produced and the amount of energy that is needed in the production process. The key technical term describing the ratio of energy returned to energy invested is called

Energy Return On Investment (EROI):

$$EROI = \frac{energy\ \ produced\ \ [EJ]}{energy\ \ invested\ \ [EJ]}$$

As a dimensionless quantity, EROI reflects the energy density and ease of access of the corresponding source of energy (Buchanan, 2019). A large/small EROI indicates that the energy from that source is easy/difficult to get. For an EROI equal to 1, there is no energy return on the energy invested. The investment would be wasted.

Since the middle of the last century the extraction of fossil fuels is getting more complex and an increasing proportion of the energy output is diverted to producing that energy (Lambert et al., 2012). Accordingly, global EROI figures for our most important fuels (except coal) have been declining for some time. Global oil and gas production went from ratios of over 80 or 90:1 in the 1930s to 35:1 in the 1990s and 18:1 in the 2000s (Lambert et al., 2013). Especially tar sands in Canada show small EROI values of maximum 11:1 (Lambert et al., 2013). This trend is not likely to reverse as renewables and other non-renewables show substantially lower EROI values than fossil fuels used decades ago (Buchanan, 2019). Nuclear power has EROI values of around 5:1 to 15:1, averaged over the entire fuel cycle (Lenzen, 2018, Lambert et al., 2013), wind power shows values of around 18:1 (Lambert et al., 2013) and hydropower can have a very high EROI for some installations, but can also be quite low. In a meta-analysis of 232 references Bhandari, et al. (2015) show that EROI values for mono- and poly-crystalline silicon PV modules vary between 6 and 16:1. Other renewables like US corn ethanol are estimated to have an EROI of less than 2:1 (Lambert et al., 2013). However, the consequences of the energy transition to a more sustainable future and lower EROI values on economic conditions and especially on commodity price developments are unclear (Court and Fizaine 2017).

Furthermore, the oil price boom between 2005 and 2008 and the subsequent market collapse, causes serious concerns among economists as to whether today's energy prices may be sufficient to guide decisions about the energy future (Hall et al. 2009). As proposed in Hall et al. (2009), the analysis of EROI values might provide an alternative view for assessing advantages and disadvantages of various energy sources. Hence, considerations of EROI values provide valuable information on future, fundamental market developments which market prices could not account for, cf. Hall et al. (2009) and Hamilton (2012).

Like all forms of economic output, also the extraction and processing of raw commodities largely depends on the amount of surplus energy available to the system. Hence, in our paper we estimate the effect of the decreasing EROI of oil on long-term commodity price developments between 1900 and 2014. Relying on the price-based EROI of Court and Fizaine (2017), we extend existing literature on long-term commodity assessments like Byrne et al. (2013) to gain a better understanding of long-run movements in commodity prices.

To the best of our knowledge, we are the first who examine the long-run effect of declining EROI of oil on an index of non-energy commodity prices. We find evidence that commodity prices depend on the amount of surplus energy available to economies. Since 1938, we show that EROI is the most influential variable and explains up to 30% of commodity price fluctuations (Chapter 4). The lower the EROI, the higher are commodity prices. During times of weak economic growth, the EROI effect on commodity prices is stronger than in times of strong economic growth. We thus conclude that simultaneously considering GDP growth rates and EROI values of most important energy sources helps to estimate fundamental effects the change in main energy sources might have on commodity price developments.

In the remainder of this paper, we continue with a literature review, followed by an overview of the data used in the model and the determination of the EROI of oil. The penultimate section determines the driving factors of commodity price developments in a structural VAR approach and highlights most important learnings of our approach while the final section concludes.

2 Literature review

Historically, commodity prices are driven by various factors and determined by long-term trends, long cycles, and short-run fluctuations (Arezki et al. 2014). A large body of literature has been developed based on the Prebisch (1950) and Singer (1950) (PS) thesis focusing on long-run commodity price trends. Authors argue that over the long run, prices of primary commodities exhibit declining trends relative to prices of manufactured goods. These findings could be explained by low-income elasticities of demand for commodities or technological and productivity differentials between industrial and non-industrial countries (Harvey et al. 2017). An excellent overview of most important papers in the field of trend analysis of long-run commodity price series is given in Baffes and Etienne (2016).

Analyzing long cycles, the literature finds strong empirical evidence that global economic growth is one of the key drivers of commodity demand (Bruno et al. 2016). Barsky and Kilian (2001) show that commodity prices are influenced by macroeconomic conditions. Especially in the early 1970s, they argue that industrial commodity price increases were consistent with an economic boom driven by monetary expansion. Similarly, Carter et al. (2011) focus on two major commodity booms and busts episodes in 1974 and 2008. As the primary reason behind this development they find contemporaneous supply and demand shocks coinciding with low inventory levels and macroeconomic shocks. Frankel (2006) examines connections between monetary policy, agriculture and mineral commodities and claims that low real interest rates lead to high real commodity prices. Based on a structural VAR model, Akram (2009) confirms that commodity prices significantly increase in response to reductions in real interest rates and a weaker US dollar. Lombardi et al. (2012) find exchange rates and economic activity to be important drivers for individual non-energy commodity prices between the 1970s and 2008.

Apart from the aforementioned key drivers of commodity prices another branch of literature focuses on the relation between energy and non-energy commodities. Between 1960 and 2005 Baffes (2007) examines the effect of crude oil prices on the prices of 35 internationally traded primary commodities. Baffes (2007) argues that oil prices affect the supply side of commodities due to fertilizer prices, transportation, or any kind of energy intensive production. Additionally, Baffes and Etienne (2016) and Baffes and Haniotis (2016) find a strong pass-through of crude oil price changes to an overall non-energy commodity index. The latter also show that real income negatively affects real agriculture prices in the long run, whereas energy costs, monetary conditions and inventories are rather short-term prices drivers. Similarly, Nazlioglu et al. (2013) suggest dynamic interrelationships between energy and agriculture markets. In contrast, Alghalith (2010) and Chang and Su (2010), and Lombardi et al. (2012) do not find direct price relations between fuel and agriculture commodity prices.

We extend the current literature by adopting the concept of energy return on investment (EROI) and its implications on commodity prices. As economic systems heavily rely on available energy, Stern (2011) assumes that when energy is scarce it might impose strong constraints on economic growth. In addition, as energy is a key input variable for the extraction and production of raw commodities, it is of great interest how changing energy availability affects the supply side of commodity prices. The economic literature on the concept of EROI and its implications for economic growth has emerged in recent years only. For a good review of the literature see Murphy (2014). He concludes that the EROI of global oil production is declining and that the relation between EROI and the price of oil is inverse and exponential. Murphy (2014) thus proposes, that declining EROI impedes long-term economic growth and will come at higher financial, energetic and environmental costs. Similar conclusions can be found in Murphy and Hall (2011) and Fizaine and Court (2016). Hall et al. (2014) give a detailed description of different types of EROI analysis and its boundaries. Court and Fizaine (2017) follow up on this analysis and introduce a price based methodology to estimate long-term global EROI of coal, oil, and gas (from 1800 to 2012). Their results are consistent with already existing estimations of global oil and gas production as in Gagnon et al. (2009) and theoretical models developed in Dale et al. (2012). Court and Fizaine (2017) conclude that the EROI of global oil productions reached its maximum value of 80:1 in the 1930s-40s and has declined subsequently. An EROI of 80:1 indicates that 80 units of energy output require one unit of energy input to produce that energy.

Combining various approaches discussed in the literature, we estimate how a decreasing EROI of oil affects commodity price developments in the following sections.

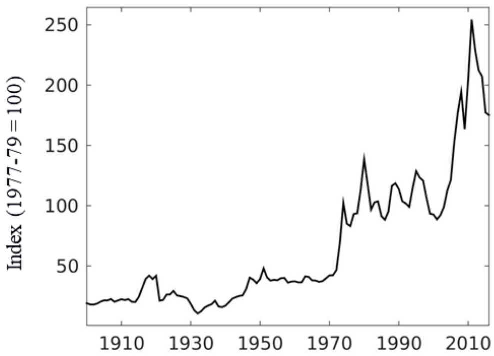
3 Data description and the measurement of EROI

We rely on the widely used Grilli and Yang (1988) commodity price index (GYCPI) to assess long-term effects of decreasing surplus energy on commodity prices. For the period 1900 to 1986 the trade-weighted index is composed of 24 primary non-fuel commodity prices deflated by the manufacturing unit value index (MUV). The MUV is one of the most frequently used deflator in the literature and is determined as a trade-weighted index of exports of manufactured commodities from France, Germany, Japan, United Kingdom, and United States to developing countries (Pfaffenzeller et al. 2007). We have updated the GYCPI based on commodity price series suggested in Pfaffenzeller et al. (2007) to 2014. Descriptive statistics of the individual commodity return series are shown in Table 1 and the detailed summary of commodities used in our study can be found in Table A1.

Figure 1 shows the GYCPI and the GYCPI relative to the MUV index. The GYCPI shows an upward trend over time whereas real commodity prices decline (GYCPI relative to MUV) until the beginning of the 2000s. Both indices exhibit sideways movements between the 1950's and the 1960's and show a commodity price boom during the 1970's. Since the early 2000's we see

Figure 1 Grilli and Yang (1988) index from 1900 to 2014 (source: Grilli and Yang, 1988).

a) Grilli-Yang commodity price index.



b) Grilli-Yang commodity price index relative to the MUV index.

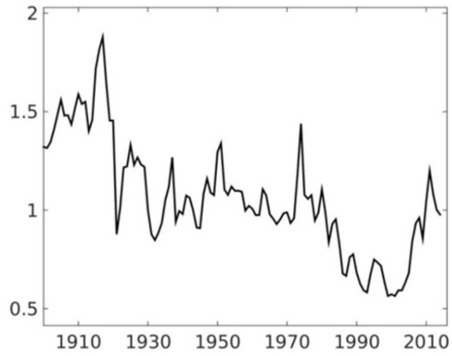


Table 1: Descriptive statistics of commodity price returns and weightings in the GYCPI between 1900 and 2014 (source: Percentage data on annual commodity prices and weightings are based on Pfaffenzeller et al., 2007 and Grilli and Yang, 1988).

Components	Weight	Mean	Standard deviation	Maximum	Minimum
Bananas	0.9	2.8	9.7	33.6	-34.4
Beef	5.1	4.0	21.4	82.6	-60.1
Cocoa	2.7	2.0	26.1	111.0	-60.9
Coffee	10.3	2.7	25.3	78.8	-60.8
Lamb	0.9	4.3	22.7	83.1	-64.6
Maize	6.8	2.1	23.5	70.5	-92.2
Palm oil	8.3	1.9	24.2	72.7	-69.5
Rice	3.0	1.6	19.5	86.7	-57.8
Sugar	7.3	1.6	35.4	113.5	-134.9
Tea	1.6	1.9	16.2	55.9	-55.8
Wheat	8.1	2.3	19.6	72.5	-51.1
Cotton	4.3	1.6	18.9	50.2	-55.0
Hides	2.3	2.1	26.0	71.5	-100.5
Jute	0.2	2.5	23.4	60.3	-78.3
Rubber	2.8	0.5	29.7	102.3	-96.2
Timber	12.0	3.3	16.5	55.1	-46.8
Tobacco	2.9	3.5	12.5	50.7	-33.1
Wool	2.7	1.9	21.4	77.0	-63.2
Aluminium	5.1	0.9	16.2	60.6	-45.0
Copper	5.9	2.6	19.4	60.3	-46.9
Lead	1.3	2.7	20.4	69.3	-56.1
Silver	1.7	3.0	21.2	72.0	-67.7
Tin	2.2	3.2	21.1	57.4	-58.0
Zinc	1.6	2.8	21.6	94.7	-54.8
Average		2.4	21.3	72.6	-64.3

an increasing trend corresponding to the second global boom in commodity markets, cf. Carter et al. (2011). In the following analysis we rely on the GYCPI relative to MUV.

Which factors drive commodity prices?

Empirical evidence suggests that commodity prices are influenced by macroeconomic conditions, geopolitical uncertainty, and monetary policy (Barsky and Kilian, 2001; Frankel, 2006; Bruno et al. 2016). First, to approximate global uncertainty, we rely on stock market risk calculated as annualized standard deviations of daily Dow Jones index data (Williamson, 2017a). For a similar approach see Byrne et al. (2013) and references therein.

Second, to estimate how monetary policy affects commodity prices we rely on real US interest rates. As a proxy variable we use short-term interest rates from Officer (2017). Until 1930 they consist of ordinary funds rates from the Federal Reserve and from 1931 to present, they are in the form of 3-months US treasury bills. Intuitively, rising interest rates lead to an increase of investments in fixed income securities as they get more interesting than risky products like commodities. This reduces the demand for commodities and leads to falling commodity prices.

Third, most important drivers of long-term commodity price developments are supply and demand. As already noted by Bruno et al. (2016), there is overwhelming empirical evidence that global economic growth is a key driver of commodity demand (Alquist and Coibion, 2014; Kilian, 2009). We use world GDP growth rates as approximation of global demand effects and obtain the data from Maddison (2013) and World Bank. Similar to Byrne et al. (2013), we estimate missing data for world GDP between 1900 and 1950 by linearly interpolating the GDP series of China, USA, India, 12 Western European countries, Latin America, Australia, New Zealand, Canada, and Japan. On the supply side, we focus on the importance of energy availability. The availability of energy is the most important input factor for non-fuel commodities due to fertilizer prices, transportation, or any kind of energy intensive production (Baffes 2007). Motivated by Hall et al. (2009) we rely on the EROI of oil to estimate how changing energy availability affects non-fuel commodity prices. Our analysis is particularly important as the EROI of conventional fossil fuels is decreasing and the EROI of most renewable and non-conventional energy alternatives is substantially lower than the EROI of conventional fossil fuels (Hall et al. 2014).

Determination of the EROI

The EROI of oil is measured as the energy output E_{out} divided by the energy input E_{in}.

$$EROI_{oil} = \frac{energy\ produced[EJ]}{energy\ invested[EJ]} = \frac{E_{out}}{E_{in}} \qquad (1)$$

The higher the EROI, the greater is the amount of surplus energy accessible to society (Hall et al. 2014). Until today, there is no single accepted procedure how to estimate EROI for different sources of energy. In order to estimate long-term EROI of oil we thus follow Court and Fizaine (2017) and King and Hall (2011) and use a price based methodology. The EROI based on Court and Fizaine (2017) represents the ratio of annual gross energy produced to annual energy invested.

The output or production boundary of the EROI is at the well-head and is estimated based on historical oil production data. The input side covers direct energy expenditures, indirect energy expenditures from physical capital investments, and direct energy embodied in what workers purchase with their payback. Hence, most important variables for the energy input side are oil prices, the global primary energy mix, monetary-return-on-investment (MROI) of the energy sector and energy intensity of capital expenditures in the primary fossil energy

[1] We do not consider storage costs explicitly as data is not available for the period considered in this paper. However, parts of these costs might be related to energy usage and thus partly covered in our EROI-factor.

sector. The final estimation of the global EROI of oil is as follows[1]:

1. Energy E_{in} invested in global oil system corresponds to the quantity of money M_{in} invested in the sector multiplied by the average energy intensity EI of capital and services installed and used.
2. For M_{in} only few data exist. M_{in} is estimated as the quantity of energy produced E_{out} by the oil sector multiplied by a proxy for annual (not levelized) production costs of oil.
3. The production costs of oil are estimated as the unitary price P of oil divided by the monetary-return-on-investment (MROI) of the oil sector. According to Court and Fizaine (2017) and Damodaran (2015), the US fossil energy sector's MROI is roughly following US long-term interest rates with a 10% risk premium.
4. Further assumption: The energy intensity EI is the same for all energy sectors and corresponds to the average energy intensity of the global economy. EI is estimated as the sum of the entire energy output from coal, oil, gas, nuclear, and renewables divided by the gross world product GWP.
5. The global EROI for oil reads as follows[2]:

$$EROI = \frac{E_{out}}{E_{in}} = \frac{E_{out}}{M_{in} * EI} = \frac{E_{out}}{\frac{P}{MROI} * E_{out} * EI} \qquad (2)$$

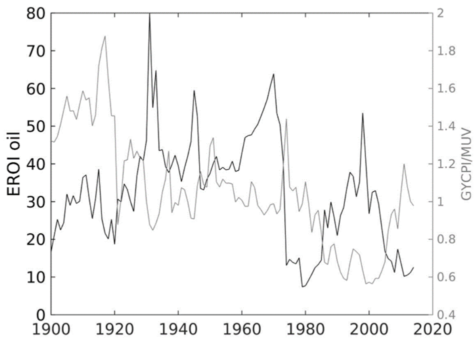
$$= \frac{MROI}{P * EI} = \frac{MROI}{P * \frac{\sum_j E_{out,j}}{GWP}},$$

$$for\ j \in (coal, oil, gas, nuclear, renewables)$$

A description of the data sources used in our study is shown in Table A2. For a more detailed view on data and estimation procedure, the interested reader should have a look at Court and Fizaine (2017). Figure 2 shows the annual price-based global EROI of oil from 1900 to 2014 compared with the GYCPI deflated by MUV. It is clear to see, that both series develop in opposite directions. Periods of high EROI values coincide with periods of low real commodity prices and vice versa.

As resources become scarce or technology makes new sources available, the EROI of any energy source may change over time (Buchanan, 2019). Hence, the EROI of oil fluctuates greatly during the past 120 years. The period from 1900 to 1937 was characterized by intensive use of coal and traditional biomass energy. Oil production was only about to start growing but increased rapidly since the late 1930s. EROI levels for oil reached its all-time high in 1931.

Figure 2 Price-based global EROI of oil (black) according to Court and Fizaine (2017) compared to GYCPI relative to MUV (grey) from 1900 to 2014 (source: own representation).



[2] All US $ values are expressed in the international Geary-Khamis $1990.

During the period from 1938 to 1976 the production of oil surged. Coal and oil were used for the production and use of war machinery. After WWII, the importance of global manufacturing and transportation increased and oil became even more important (Hall et al. 2014). The EROI of oil reached its highest average level during this period and its second peak in 1970. US oil production peaked in the same year. From this year on, OPEC oil has gained increasing importance for world supply. Hence, the EROI of oil decreased and oil prices rose subsequently reflecting the increased amount of energy needed to acquire this fuel, cf. Hall et al. (2014) and Hall and Klitgaard (2012).

In the beginning of the period from 1977 to 2014 the Iranian revolution (1978/79) and Iran-Iraq war (beginning of 1980) caused high oil prices and the oil price shock in 1979. Oil extractions which were uneconomic before becoming economic during this period, lead to to lower EROI values, cf. Guilford et al. (2011) and Hall et al. (2014). The following years between mid-80s and early 90s can be described as a period of abundant oil and falling prices which resulted in less oil explorations. Since the oil price peak in 2008 the introduction of new drilling techniques again rapidly increased the oil production in the US. However, over the past two decades the EROI of oil is decreasing as also shown in Murphy and Hall (2011) and Tverberg (2012).

In the following section we investigate to what extend the changing level of EROI affects an index of non-fuel commodity prices.

4 Model description and results

Based on yearly data for $\boldsymbol{Yt} = (\Delta EROI_t, Risk_t, \Delta GDP_t, IR_t, \Delta GYCPI_t)$ we examine the effect of changing net energy availability on commodity prices within a structural VAR approach. Within this model, $EROI_t$ is the log energy returned on investment for oil, $Risk_t$ measures the risk of geopolitical and monetary uncertainty as annualized standard deviations of daily Dow Jones index data, GDP_t corresponds to log world GDP. Until 1930, IR_t are the real US interest rates based on ordinary funds rates from the Federal Reserve and from 1931 to present IR_t are 3- months treasury bills of the US. $GYCPI_t$ is the log of the Grilli-Yang commodity price index deflated by MUV. To ensure stationary time series we apply the fist-order difference operator Δ. We define the structural VAR approach with p lags as follows

$$\boldsymbol{C}_0\boldsymbol{Y}_t = \sum_{i=1}^{p} \boldsymbol{C}_i\boldsymbol{Y}_{t-i} + \epsilon_t \quad (3)$$

$\boldsymbol{\epsilon t}$ is the vector of serially and mutually uncorrelated structural shocks and we determine the lag length p according to the Schwarz (1978) information criterion. The matrix $\boldsymbol{C}_0^{-1}$ given in Equation 3 has a recursive structure with reduced-form errors $\boldsymbol{ut}$ which are obtained from $\boldsymbol{ut} = \boldsymbol{C}_0^{-1}\boldsymbol{\epsilon t}$:

$$u_t := \begin{pmatrix} u_t^{\Delta EROI} \\ u_t^{Risk} \\ u_t^{\Delta GDP} \\ u_t^{IR} \\ u_t^{\Delta GYCPI} \end{pmatrix} = \begin{bmatrix} c_{11} & 0 & 0 & 0 & 0 \\ c_{21} & c_{22} & 0 & 0 & 0 \\ c_{31} & c_{32} & c_{33} & 0 & 0 \\ c_{41} & c_{42} & c_{43} & c_{44} & 0 \\ c_{51} & c_{52} & c_{53} & c_{54} & c_{55} \end{bmatrix} \begin{pmatrix} \epsilon_t^{EROI\ shock} \\ \epsilon_t^{risk\ shock} \\ \epsilon_t^{economic\ growth\ shock} \\ \epsilon_t^{interest\ rate\ shock} \\ \epsilon_t^{commodity\ specific\ shock} \end{pmatrix} \quad (4)$$

As we rely on the orthogonalization of our VAR system based on a Cholesky decomposition of the reduced-form error's covariance matrix, our structural system is contemporaneously recursive[3]. The set-up of the variables is based on the following assumptions:

1. Economic growth and commodity prices are strongly driven by energy input. As the energy which is used in the extraction process is not available for generating economic output, lower EROI values can have strong influence on economic activity (Buchanan, 2019). Hence, a shock in the EROI of oil will not only have implications on GDP growth rates but also on commodity prices. In addition, changing EROI of oil might simultane-

[3] A similar model set up can be found in Kilian (2009), Wang et al. (2014), and Lübbers and Posch (2017).

ously affect global economic uncertainty and risk in financial markets due to changing energy prices.
2. Risk and uncertainty simultaneously affect economic growth, monetary policies and commodity prices as argued in Frankel (2006).
3. There is overwhelming empirical evidence that global economic growth is a key driver of commodity demand, as noted in Bruno et al. (2016). A shock in world GDP growth rates thus changes global demands for raw commodities and thereby its prices.
4. Monetary policies are adapted to changes in economic conditions. As suggested in Frankel (2006) and Akram (2009), changes in interest rates simultaneously affect commodity prices. Rising interest rates might reduce the demand for commodities and lead to falling commodity prices.
5. Finally, commodity prices are simultaneously affected by all other variables.

How do commodity prices react to shocks in EROI and GDP growth rates?

We start by estimating the structural VAR for $\boldsymbol{Yt} = (\Delta EROI_t, Risk_t, \Delta GDP_t, IR_t, \Delta GYCPI_t)$ to evaluate the effect of varying EROI levels over time and for various sample periods. As we focus on supply and demand shocks, Figure 3 shows the responses of the GYCPI to shocks in the EROI of oil and world GDP growth rates. The 95% confidence bands are estimated from 1000 Monte Carlo simulations. The impulse responses of the GYCPI to real interest rates and uncertainty shocks are shown in Figure A3.

The period between *1900* and *1937* can be characterized by intensive use of coal and traditional biomass energy rather than oil. Hence, oil's EROI shocks on GYCPI do not show significant effects on commodity returns. A shock in economic growth rates significantly affects the GYCPI for a short period of time and after two years only. Possibly, this might be explained by volatile economic conditions and WWI.

The following years from 1938 to 1976 can be described as a period of cheap and abundant fossil energy. The total energy consumption per person has more than doubled (Figure 4) and the average level of the EROI of oil reached its highest values (Figure 2). A shock in the EROI of oil thus negatively (contrarily) affects the GYCPI. Intuitively, rising EROI values lead to more surplus energy and decreasing energy costs. This in turn results in lower commodity prices. However, commodity prices seem to overreact on EROI shocks as its effect becomes significantly positive after two years and insignificant subsequently. Shocks in economic growth only show little to no significant effects on the GYCPI.

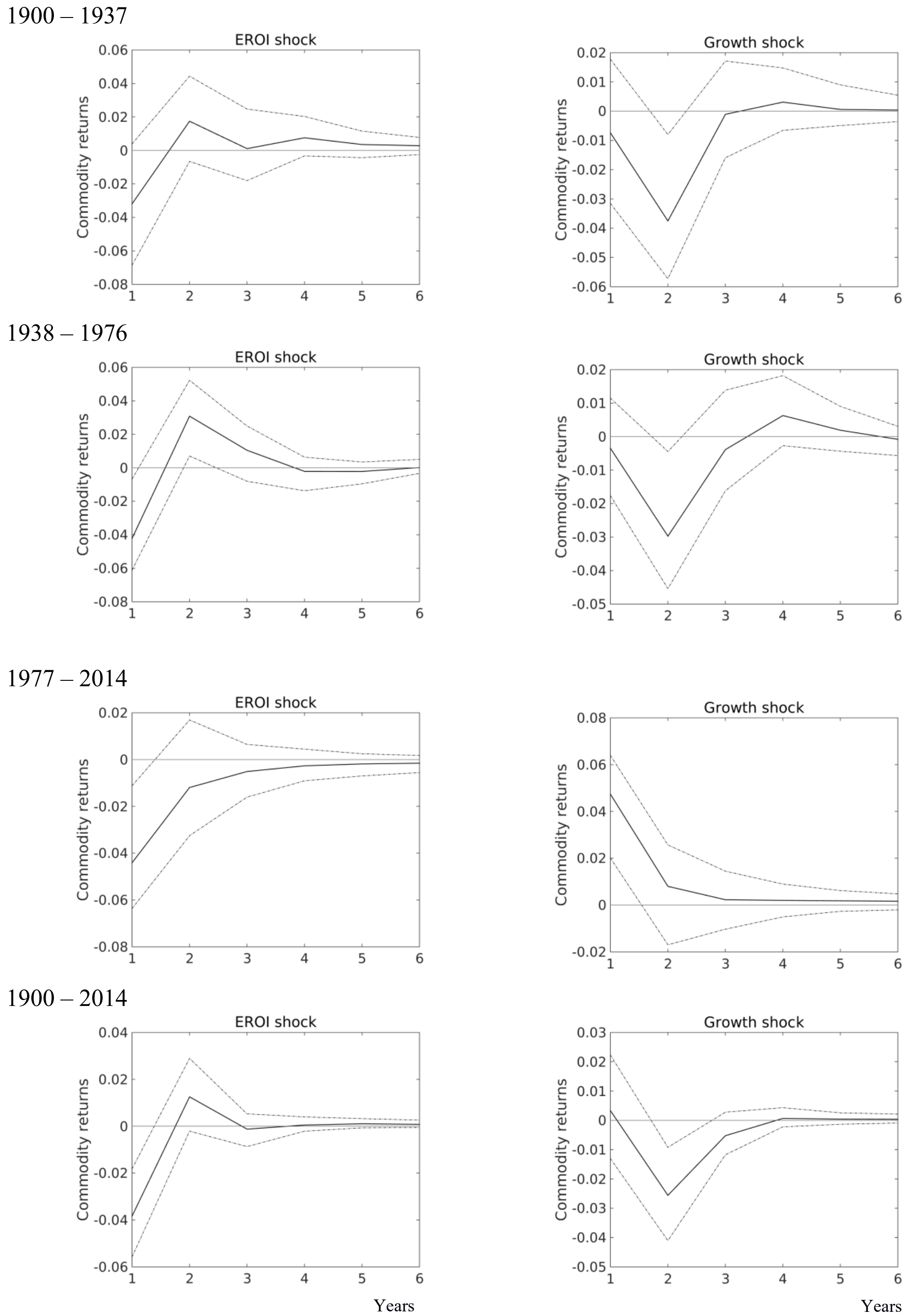
The most striking results of Figure 3 are the distinct negative responses of commodity prices to shocks in oil EROI values during the last period from *1977* to *2014*. This period is characterized by strong economic growth (Figure 4) but lower average EROI values (Figure 2). We conclude, that also decreasing EROI values have a distinct and significant effect on commodity prices. Intuitively, the lower the EROI the less surplus energy is available and the more expansive are commodity prices.

In contrast, the effect of world GDP growth rates shocks on GYCPI is significantly positive. However, the impact of EROI and GDP on GYCPI appears to be of the same size. The time to recover from a shock in EROI and GDP growth rates is approximately 6 months. Over the entire period (*1900* to *2014*) shocks in the EROI of oil are more important for commodity price movements than shocks in GDP growth rates. Hence, changes on the supply side seem to be more relevant for commodity price movements than those on the demand side.

What is the explanatory ability of our main drivers' shocks on commodity prices?

In order to examine the amount of information each variable contributes to the other variables in our VAR model, Table 2 summarizes the results of our Forecast Error Variance Decomposition (FEVD) at forecast horizons of one and

Figure 3 Responses of GYCPI to structural demand and supply shocks (source: own representation).[4]



[4] The graphs show the response of the Grilli-Yang index to a generalized one standard deviation innovation in the EROI of oil and world economic growth for different periods of time. The 95% confidence bands are based on 1000 Monte Carlo simulations.

Figure 4 World total GDP compared to world energy consumption per person (data sources: British Petroleum, 2017 and United Nations population division).[5]

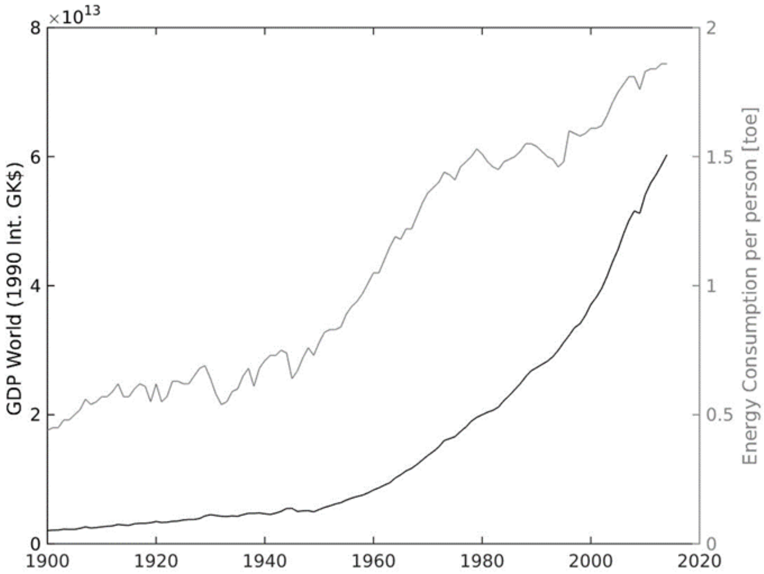


Table 2 Percentage contribution of fundamental factors to variations in the GYCPI.[6]

Period	Average EROI	Forecast horizon [years]	Shocks in EROI	Risk	GDP growth rate	Interest rate	Commodity prices (GYCPI)
1900 - 1937	32.8	1	9.2	1.0	0.5	58.6	30.7
		5	9.8	5.4	10.4	49.9	24.5
1938 - 1976	40.0	1	27.7	9.4	0.2	0.0	62.8
		5	30.7	11.0	10.3	1.2	46.7
1977- 2014	20.5	1	19.4	0.0	22.5	0.3	57.8
		5	19.9	0.0	21.8	1.8	56.5
1900 - 2014	31.3	1	13.6	0.0	0.1	12.0	74.3
		5	13.6	1.5	5.8	11.2	68.0

[5] The world total GDP (black) values are expressed in the international Geary-Khamis 1990$ and energy consumption is given in tons of oil equivalent (toe) per person (grey).
[6] This table compares the percentage contribution of different shocks to the Grilli-Yang index for various time periods and forecast horizons of one and five years.

five years. Between 1900 and 1937 real interest rate shocks account for more than half of the variation in commodity prices. This confirms the findings of Frankel (2006) who claims that low real interest rates lead to high real commodity prices, cf. Figure A3. EROI, risk, and GDP growth are less important for commodity prices within that time period. However, demand shocks and supply shocks both almost account for 10% of commodity price variations over the five-year forecast horizon. During the second period (1938 to 1976), the most important variables are EROI (30.7%), risk (11%), and GDP growth rates (10.3%) which account for 52% of the variations in commodity prices. The importance of these variables reflects macroeconomic and political developments during these years. After WWII strong economic growth, increased manufacturing and transportation drove demand for fossil energy products (Hall et al. 2014) and raw commodities.

From *1977* to *2014* economic growth has surged (Figure 4). Our FEVD analysis reveals that GDP growth rates account for more variation in real commodity price changes (22.5%) than shocks in the energy availability (19.4%). Together, shocks in EROI and GDP growth rates almost account for more than 40% of the variation in commodity prices. Interest rates and uncertainty of financial markets only play minor roles. Interestingly, the low impact of financial risk on commodity price fluctuations also suggests that financial markets are not important for long-run commodity price fluctuations. These findings are in line with parts of the literature examining the effect of financial speculation on commodity prices. While the correlation between commodity and equity returns surged during the financial crisis in 2008, Bruno et al. (2016) could not find a significant long-run correlation between those two markets.

Over the entire period (*1900* to *2014*) and in line with Frankel (2006) we find that real interest rates play a dominant role for the fluctuation of commodity prices. However, its effect was strongest during the beginning of the 20th century and became less important over the years. In accordance with Barsky and Kilian (2001) who argue that industrial commodity price increases in early 1970s were consistent with an economic boom driven by monetary expansion, our results show GDP growth rates to be important for commodity price variations only since the early 1970s. As EROI is the most influential variable for commodity price variations since 1938 explaining more than 19% of commodity price fluctuations, our results also confirm Carter et al. (2011) mentioning the importance of supply and demand shocks for commodity price booms in 1974 and 2008. Our findings thus contradict the results of Alghalith (2010), Chang and Su (2010), and Lombardi et al. (2012) who do not find direct relations between fuel and commodity prices.

Empirically, we show that during the past 100 years, periods of low EROI have been correlated with higher commodity prices and vice versa (compare Figure 2). Commodity prices thus depend on the amount of surplus energy available to society. Nonetheless, during times of strong economic growth, the effect of EROI on commodity prices is slightly lower than in times of weaker economic growth (see Table 2 and Figure 2 and 3). Simultaneously considering GDP growth rates and EROI values of most important energy sources might thus help to estimate the effect of a changing energy supply mix on long-term commodity price developments.

Model extensions – Comparing our price-based EROI to estimations of EROI values in the literature, Court and Fizaine (2017) show that the price-based approach is consistent with the theoretical model in Dale et al. (2011) and follows the same trend as in Gagnon et al. (2009). To further assess the robustness of our findings we also tested the sensitivity of the price-based EROI and our results to changes in the monetary-return-on-investment (MROI) as suggested in Court and Fizaine (2017). Based on a document of te American Petroleum Institute

(API 2016) quoting an average annual profit assumption of the entire US oil and gas industry between 5 and 15% we follow King and Hall (2011), King et al. (2015), and Court and Fizaine (2017) and also assume a constant MROI equal to 1.1. However, variations of the MROI did not significantly change the outcome of our results.

5 Outlook

As the most important finding of our paper is that a changing EROI of oil accounts for up to 30% of the variation of a commodity price index, we conclude that commodity prices depend on the amount of surplus energy available for society. Additionally, we show that over the past 100 years, periods of low EROI have been correlated with higher commodity prices and vice versa. While there are many factors driving economic growth and commodity prices, certainly, the availability of energy will be more and more crucial for future commodity price developments. Even though our paper focuses on oil, our results are an indicator for how future decreasing EROI values of renewable energies might fundamentally increase commodity prices. In the long run, this places special challenges not only for our society but also for energy- and commodity- intensive industries like the chemical industry. On this account, companies today need to fundamentally adapt future scenarios in order to transform business models and to lower dependence on energy and raw commodities. As an example, the adoption of new business practices like a circular economy would allow companies to develop strategies that increase its EROI and reduce its large demand for external sources of energy and raw materials.

Based on the idea of Hall et al. (2009) who focus on the question what a minimum EROI for sustainable societies is, future research may extend our results in this direction and focus on the question whether a critical EROI for stable commodity price developments exists.

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Appendix

Table A1: Data sources of commodity price series (source: own representation).

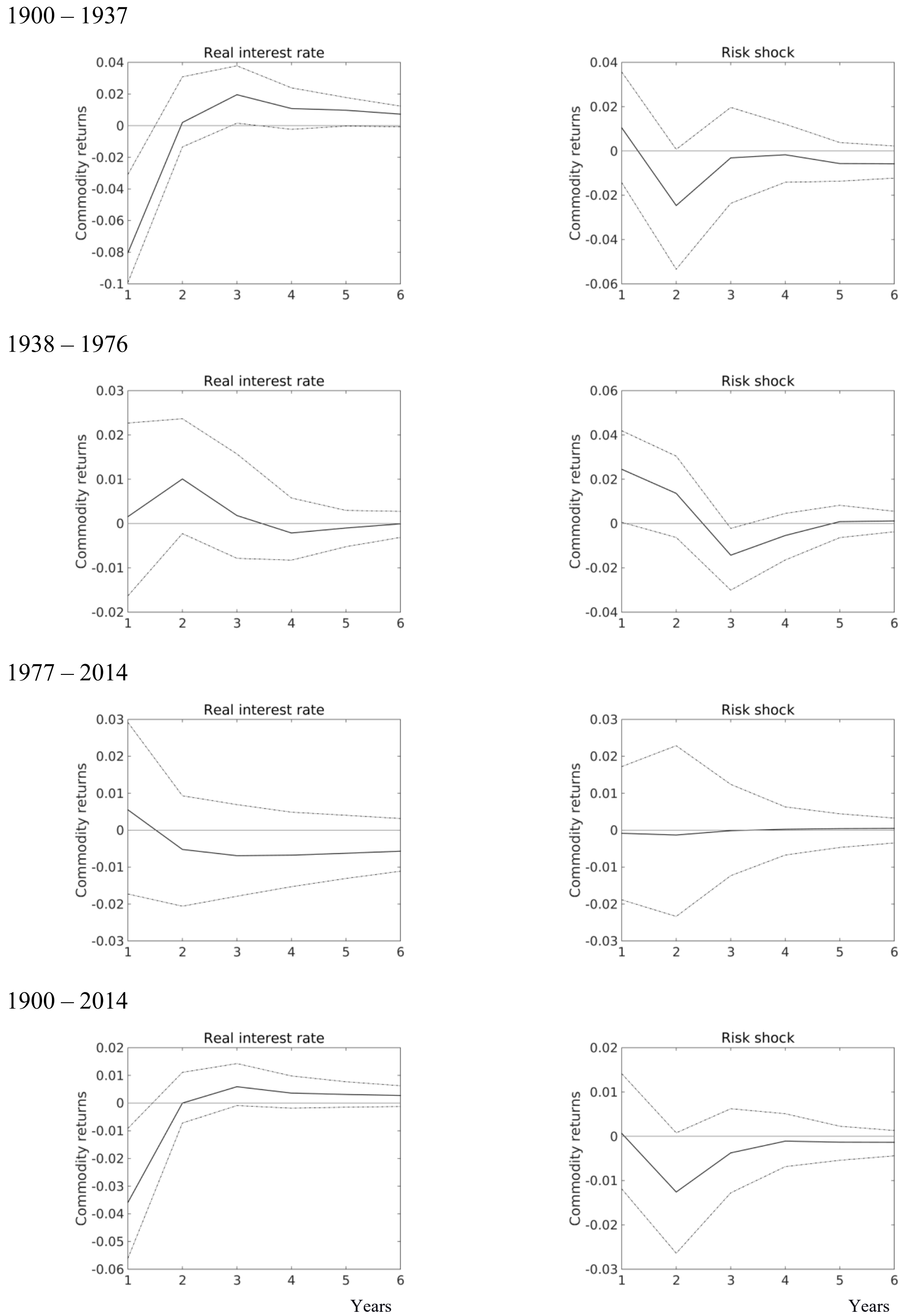
Commodity	Description of price series	Data source
Aluminum	London Metal Exchange (LME), unalloyed primary ingots, high grade, minimum 99.7% purity	World Bank Development Prospects Group's primary commodity price database
Banana	Central and South American, U.S. import price, free on truck (f.o.t.) gulf ports	World Bank Development Prospects Group's primary commodity price database
Beef	Australian and New Zealand 85% lean fores	IMF commodity price tables series PBEEF
Cocoa	International Cocoa Organization daily price, average of the first three positions on the terminal markets of New York and London, nearest three future trading months	World Bank Development Prospects Group's primary commodity price database
Coffee	International Coffee Organization, other mild Arabica	World Bank Development Prospects Group's primary commodity price database
Copper	LME grade A minimum 99.9935% purity, cathodes and wire bar shapes, settlement price	World Bank Development Prospects Group's primary commodity price database
Cotton	Cotton Outlook A Index, middling 1 3/32 inch staple, Europe cost, insurance, and freight (c.i.f.)	World Bank Development Prospects Group's primary commodity price database
Hides	Heavy native steers, over 53 pounds	IMF commodity price tables series PHIDE
Jute	Raw white D, free on board (f.o.b.) Chittagong	World Bank and quoted on the Pink Sheets and FAO
Lamb	New Zealand, frozen whole carcasses, wholesale price, London	World Bank Development Prospects Group's primary commodity price database
Lead	LME refined, 99.97% purity, settlement price	World Bank Development Prospects Group's primary commodity price database
Maize	U.S. No.2 yellow, f.o.b. gulf port	World Bank Development Prospects Group's primary commodity price database
Palm oil	5% bulk, Malaysian, c.i.f. NW Europe	World Bank Development Prospects Group's primary commodity price database

Rice	Thai 5%, milled, indicative price based on weekly surveys of export transactions, government standard, f.o.b. Bangkok	World Bank Development Prospects Group's primary commodity price database
Rubber	RSS no.1 Rubber Traders Association spot New York	World Bank Development Prospects Group's primary commodity price database
Silver	Handy and Harman 99.9% New York	World Bank Development Prospects Group's primary commodity price database
Sugar	International Sugar Agreement daily price, raw, f.o.b. and stowed at greater Caribbean ports	World Bank Development Prospects Group's primary commodity price database
Tea	Three-auction average (Kolkata, Colombo, Mombasa)	World Bank Development Prospects Group's primary commodity price database
Timber	UK import unit values, SITC Rev.2 series 2482 (sawn wood, coniferous species)	OECD international trade by commodities statistics through ESDS International
Tin	LME 99.85% purity, settlement price	World Bank Development Prospects Group's primary commodity price database
Tobacco	U.S. import unit values, unmanufactured leaves	World Bank Development Prospects Group's primary commodity price database
Wheat	No.1 Canadian western red spring, in store, St. Lawrence, export price	World Bank Development Prospects Group's primary commodity price database
Wool	wool, coarse, 23 micron, Australian Wool Exchange spot quote	IMF commodity price tables series PWOOLC
Zinc	LME, special high grade, minimum 99.995% purity, weekly average bid/asked price, official morning session	World Bank Development Prospects Group's primary commodity price database

Table A2: Data sources of the EROI of oil (source: own representation).

Item	Source
World primary energy production	
Coal, oil, gas, nuclear, hydro, other renewables	(TheShiftProject 2015), built on (Etemad and Luciani 1991) and (EIA 2014)
Biofuels (wood fuel, crop residues, modern biofuels)	(Smil 2016)
Oil prices	(BritishPetroleum 2017)
CPI US	(Williamson 2017b)
MROI, long-term interest rate (US LTIR)	(Officer 2017)

Figure A3: Responses of GYCPI to structural real interest rate and uncertainty shocks (source: own representation).[7]



[7] The graphs show the response of the GYCPI to a generalized one standard deviation innovation in real interest rates and risk for different periods of time. Also shown are the 95% confidence bands based on 1000 Monte Carlo simulations.

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Thank you for your contribution!

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