A Couple of Spills a Year, That's Normal? Learning and Greenwashing in the Pipeline Industry

Julian Barg
jbarg.phd@ivey.ca
Ivey Business School

Abstract

From 2000 to 2020, the standardized spill volume of refined petroleum pipelines has stayed constant at about 15 bbl per billion barrel-miles transported. In contrast, from 1980 to 2000, standardized spill volume had about halved. This dissertation researches why pipeline operators in the US keep causing and getting away with pipeline spills. The dissertation uses two lenses, organizational learning and greenwashing. These lenses reveal why, despite continuous efforts by engineers, the safety record of the industry has stagnated. The learning literature suggests that it is commonplace for organizational learning to converge at a high level of performance, as observed in the pipeline industry. Greenwashing is a strategy for organizations to escape negative consequences for poor environmental performance.

The first chapter reveals the mechanisms behind the convergence in organizational learning. The empirical section uses a dataset of 6,147 pipeline spills, and qualitative data on 10 significant pipeline spill. This research reveals that valid learning only occurs in response to the spills that an operator experiences. For a general theory of learning, the empirical findings suggests that learning converges when the organization or system that learns has developed a high degree of complexity. Because of this complexity, learning in response to triggers such as failures is not sufficient anymore for making aggregate improvements. Learning turns into a perpetual game of whack-a-mole.

The second chapter takes an encompassing look at the learning literature and promotes a more universal, new theory on the validity and reliability of learning. When learning goes beyond incremental improvements and touches on fundamental assumptions, organizations or industries can break out of their trajectory. However, many learning outcomes that have been thought of as "breakthroughs" have not led to the promised revolutions in the market. Validity and reliability fill an important gap in the literature of learning: even when learning produces sensible and internally consistent insights, these insights are meaningless if they do not serve for the organization to better understand, predict, and control existing

problems, limitations, or bottlenecks–that is, if the knowledge is not valid. And valid knowledge still fails to make an impact if it is not reliable, meaning not shared across the organizational members who are to implement the insights.

Finally, the third chapter discusses how pipeline operators keep in check the backlash for the environmental pollution that they cause. Pipeline operators shield themselves from criticism using new technology. When an operator causes a spill, the operator can point to the latest development in the constant flow of new technology as a remedy for future spills. The third chapter uses the same data on pipeline spills and pipeline networks as the first chapter, and adds text data from operators and industry level actors. I then track empirically how these patterns of greenwashing are diffused in the pipeline industry. This analysis sheds light on the role of industry level actors (such as the American Petroleum Institute) in greenwashing.

Keywords: organizational learning, greenwashing, industry level, population level, pipeline spills

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Introduction

> "[T]here is perhaps an over-emphasis of technology in [Leak Detection Systems]. A recurring theme is that of false alarms. The implication is that [a Leak Detection System] is expected to perform as an elementary industrial automation alarm, with an on/off state and six-sigma reliability. Any alarm that does not correspond to an actual leak is, with this thinking, an indicator of a failure of the LDS system. Instead, multiple technical studies confirm that far more thought is required in dealing with leak alarms" – Shaw et al. (2012, p. 2-3).

How does an industry get stuck with a never-ending series of pollution events? It is the conventional view of organizational learning that performance measures, after initially exhibiting fast improvements, will settle at at a certain level (Argote 2013b). In other words, learning levels off. The *organizational knowledge* view–the dominant stream of the learning literature–suggests that organizations accumulate knowledge which is held by individuals, in routines, or in transactive memory systems (Argote & Miron-Spektor 2011, Bingham & Eisenhardt 2011). New knowledge is added to an existing "stock", presumably until there is no more new insights to be added. Disclosure of the outcomes of this learning process then is a subsequent, separate step–the organization makes a strategic decision as to which outcomes to share with stakeholders. To withhold negative information on environmental performance in this step would constitute greenwashing (Lyon & Maxwell 2011).

An alternative view suggests that organizations can break out of existing trajectories and escape their constraints through learning–but that to do so requires a considerable rethinking of existing paradigms (March 2010). For instance, an organization can reimagine how it measures performance (Argyris & Schön 1978). This is consistent with the *organizational routines* view, which holds that organizations develop not knowledge but patterns of action in stable environments (Bingham & Eisenhardt 2011). The organizational routines view also postulates that in the absence of significant interventions, intricate but ultimately obsolete systems develop, for instance ones that rely on outdated technologies (March 1991). With sufficient complexity, these systems can generate a never-ending stream of unexpected interactions and externalities, which then become relevant for sustainability research when the organization or industry has a catastrophic potential (Beck 1992, Perrow 1984). One would hope for stakeholders to be able to identify the pattern of unexpected interactions and externalities, but under an inadequate environmental regime the organization or industry can escape scrutiny through greenwashing (Lyon & Montgomery 2015).

The inconsistent predictions of the two views, and their implications for persistent environmental pollution raises two questions. The first chapter covers the first question (1) *how does the convergence of performance measures take place?* When the convergence has taken place in an organization or industry, do we see evidence for either the organizational knowledge or the organizational routines view? The organizational knowledge view suggests that once performance has converged, either no new knowledge is gained, or knowledge disappears at the same rate as it is produced (Argote 2013a). The organizational routines view makes no such prediction, instead, if that view was accurate we would see increasingly intricate routines with ultimately have little impact on performance.

An obvious extension to the first question that the second chapter addresses is a look at possibilities for organizations to break out of a state of convergence. The *organizational routines* literature holds that organizations can break out of a state of convergence through what that literature calls either double-loop learning (Argyris & Schön 1978) or high-intellect learning (March 2010). Two overlooked attributes of knowledge, *validity* and *reliability* could mend the split between the two streams of the organizational learning literature. *Validity* describes whether knowledge does allow an organization to better understand, predict, and control problems, such as technological limitations or bottlenecks.

Reliability describes the degree to which member of the organization have command of the knowledge (Rerup & Zbaracki forthcoming). Validity and reliability allow for a critical view on the first question, and whether that state of convergence is inevitable.

The state of convergence should be fairly obvious to stakeholders when environmental pollution is involved. The second research question addresses the difficulties that continuous environmental pollution would be expected to entail. (2) *How does an organization manage–or greenwash–its convergence to a state of constant pollution?* If the state of convergence is obvious for observers, one would expect calls for substantive change to be quite loud. But the pipeline industry has maintained the status quo for twenty years, which presumably requires an effort to maintain the status quo rather than just an absence of efforts to break out of the state of convergence. This research question is covered in the third chapter.

To answer the research questions, this dissertation employs data on the US pipeline industry. The pipeline industry offers an advantage over other industries with regard to studying environmental impacts, learning, and greenwashing, in that the industry's environmental pollution very much takes place in the public. Unlike other industries, pipeline spills do not occur inside private plants, locked away from the public eye. Pipeline spills usually occur on public land that the pipeline operator has only acquired the right-of-way of. Pipeline spills also receive a lot of attention from the press, government agencies, and environmental grassroot organizations. These actors pay particular attention to large pipeline spills, which make up for a majority of annual spill volume. Finally, the scrutiny of oil spills also ensures that the reported data is more accurate. Government-employed emergency responders are on site alongside the company employees and can ensure a more accurate reporting of pollution data than is the case for routine environmental emissions.

Quantitative data from 2004-2019 allows us to observe learning and greenwashing in the pipeline industry. For this period of time, data is available from the Pipeline and

Hazardous Materials Safety Administration (PHMSA) on how much oil each American operator transported over what distance every year. PHMSA also provides a dataset that contains data on each individual pipeline spill that occurred over that period of time.[1]. Data on the spills includes a narrative, how much oil was spilled and recovered, and what other impacts (e.g., injuries or deaths) occurred. Over the 16 years of the observation period, 6,147 pipeline spills were recorded, including 2,246 that the PHMSA classified as significant based on either a spill volume of over 50 barrels, more than $50k in damages, or a casualty, injury, fire or explosion. Whereas crude oil pipelines period showed a significant improvement in pipeline safety over the observation period, the standardized spill volume of refined petroleum pipelines stayed as an almost constant rate of about 15bbl per billion barrel-miles transported (see Figure 1).

Qualitative data provides an understanding of the mechanisms of learning in the pipeline industry. That constant spill rate for refined petroleum pipelines is surprising, given the significant technological advancements in the areas of inline inspection tools, leak detection, and SCADA systems which allow for the remote supervision and control of pipelines. A repository on the largest or otherwise significant pipeline spills by the National Transportation Safety Board (NTSB) provides an in-depth understanding of accident causes. Since 1969, NTSB has authored 142 accident reports and briefs.[2]. For this dissertation I select the 10 most recent full accident reports. As a robustness check, I also select the 15 most significant accidents according to spill volume, net loss, number of injuries and fatalities, and property damage (top 3 per category), and collect independent archival data on these spills. As of 2020, little empirical research exists on the pipeline industry. Park and Rogan (2019) uses the PHMSA dataset to study how reputation affects relationships with exchange partners. Zakikhani, Nasiri, and Zayed (2020) review the research into pipeline failures in the area of engineering, which has largely ignored

[1] See `https://www.phmsa.dot.gov/data-and-statistics/pipeline/source-data`, accessed 2020-08-30

[2] See `https://www.ntsb.gov/investigations/AccidentReports/Pages/pipeline.aspx`, accessed 2020-08-30

organizational factors. More generally, oil spills are also covered by works in biology (in particular Burger 1997) and the oil industry by works in sociology and history (e.g., Dochuk 2019).

Finally, this dissertation uses text and network data for track greenwashing in the pipeline industry. Headquarter locations and board memberships (BoardEx) uncover connections between pipeline operators. Documents by the American Petroleum Institute (API) and the Association of Oil Pipe Lines (AOPL) reveal developments of the industry level. In addition, this research uses annual reports and safety reports to determine the strategies pursued by individual operators. Natural Language Processing (NLP)–specifically, topic modeling–reveals trends and show their diffusion through the pipeline industry. Finally, we can compare trends with the topics that emerge from the narratives on pipeline spill to distinguish substantive and non-substantive trends.

The context of pipeline spills is suitable for both questions on learning and greenwashing. Pipeline spills, such as other failures, are catalysts for learning (March 1991). In the pipeline industry, learning has high visibility after large pipeline spills take place. We can observe the learning process independent of its outcomes better than in other contexts. Oil spills also bring pipeline operators under high scrutiny. As a result, pipeline safety often enters the public debate. The American Petroleum Institute (API) and the Association of Oil Pipe Lines (AOPL) discuss pipeline safety and their communication strategy in a semi-public fashion. Documents by operators on pipeline safety are also public and widely available. When greenwashing takes place in the pipeline industry, it is a public affair. It is thus easier to obtain data on learning and greenwashing for this industry, compared to most other industries, which operate far less on public lands.

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Some of the findings of this dissertation might not be fully generalizable. Pipeline systems, with their manifold interactions and catastrophic potential are a great example of the complex systems and externalities discussed by Perrow (1984) and citetBeck1992. The challenges associated with growing complexity may not be present in all other contexts. In particular, uncoupled production methods can allow for much reduced interactive potential. In these contexts, convergence of performance measures and greenwashing might take on a different shape. The complexity of pipeline systems stems from the interaction of mechanics, physics (fluid dynamics are notoriously complicated are of physics), and a complicated command structure. The diverse geography and many jurisdictions of the US also add to the complexity. In addition, there is an economic incentive to run pipeline infrastructure at a very high utilization rate and throughput, e.g., by frequently changing the commodity to be transported according to demand.[3] Altogether, the complexity and interactions are not far off from what Perrow (1984) observed for nuclear power plants. Many other industries constitute complex systems because of their elaborate supply chain structures, a future avenue of research would thus be whether these complex supply chains bring about the same limits to learning.

I make four contributions with this research. (1) This dissertation introduces a context where organizational learning has "bottomed out" and analyzes how learning plays out under these circumstances. The context allows us to study learning despite the absence of aggregate, quantitative improvements in performance measures because (a) we can observe the process of learning independent from the outcome in qualitative data, and (b) rich data, including textual descriptions, is available on the object of learning–individual pipeline spills. This rich data allows us to distinguish a "dynamic" state where performance measures are constant because learning and emerging challenges cancel each other out from a hypothetical "state of equilibrium" where there is no new knowledge to be obtained. Thus, this dissertation brings to the fore a state that large swaths of the learning literature

[3] Although pipelines are generally optimized for transporting specific commodities, in principle any pipeline can transport almost any commodity when demand or supply changes.

have taken for granted: the "end of learning" period where performance measures make it appear as if the organization has come to a standstill. At least for this case of a complex system with catastrophic

(2) This dissertation also makes a contribution to the discourse regarding environmental sustainability and technology. The sustainability research community is split as to the role of technology for sustainability. Some work leans more toward a technocentric view with little to no consideration of social systems, for instance in research on low-carbon electricity (e.g., Greenblatt et al. 2017). Other authors emphasize the need for changes to the political and economic system in order reduce damages to the planet, such as the degrowth discourse (Kallis et al. 2018). With regard to that debate, the findings of this research highlight the role that system complexity and unexpected externalities play for continued pollution. The pipeline industry provides a very vivid example of the limits to depolluting existing technology. Further, the greenwashing in the pipeline industry that this research surfaces should act as a cautionary tale on the role and purpose of technology in communication.

(3) This dissertation moves forward theory on learning by highlighting the considerable effort necessary to leave an existing trajectory. New knowledge needs to be created that is both valid and reliable, which requires for an organization or industry to collectively question preexisting fundamental assumptions. Applied to pipeline spills, this would imply that if society was to collectively decide that oil spills at the current level are not acceptable, then we should not rely on the industry to develop technology and make changes in the current fashion. A more fundamental rethinking of the (physical and political) system of energy delivery would be necessary.

(4) The empirical research on greenwashing highlights the potentially malevolent role that industry level organizations can play, and that technology should be taken with reservation. Actors in the pipeline industry are aware of the possibility to created a better image by creating an association between pipelines and high-tech, even in the absence of

better safety performance. These actors may also be aware that is almost impossible for laymen to rebut the validity of technology that is built on decades of engineering research, and that hence the industry can safely entrench itself in this modern realm.

Structure

The first chapter focuses on the empirical context, the stagnation of pipeline safety. The chapter introduces the notion of convergence in performance measures, as introduced by the *learning curves* literature, which later developed into the *organizational knowledge* view (Argote 2013b). This observation of convergence, which we also see in the pipeline industry, leads to the first research question, *how does the convergence of performance measures take place?* One might intuitively assume that when a performance measures stay constant, no learning takes place. The qualitative data speaks to this assumption, and shows that in the pipeline industry, indeed, organizational learning still takes place. The quantitative data is then used to show that while problems are addressed with learning, new, unique problems constantly emerge. This is consistent with research on complex systems and externalities of modern technology (Beck 1992, Perrow 1984). Finally, the discussion section raises the alternative view, *organizational routines*, and introduces the notion that a further reduction of pipeline spills requires a more radical rethinking of existing paradigms, including technology that is used. If the status quo remains as is, the research suggests that pipeline spills will continue, despite organizations learning from spills.

The second chapter begins as a review of the organizational learning literature. The review is divided into two sections. The first section maps out the *organizational knowledge* stream of the literature, including some fundamental work on *learning curves*. The second section outlines the literature on *organizational routines*. As a next step, the chapter turns to the fundamental difference between the two approaches. The organizational knowledge stream only recognizes learning when it occurs within the current structure–such as improvements in a specific metric–whereas the organizational routines literature recognizes radical departures as learning. These radical departures may compete with or invalidate previous insights, which represents a considerable departure from organizational knowledge stream. To reconcile the two views to some degree, the chapter finally introduces the concept of *validity* and *reliability* of knowledge (Rerup & Zbaracki forthcoming).

The third chapter turns to greenwashing this chapter returns the focus to the empirical context of the pipeline industry. After a brief introduction of greenwashing, the chapter lays out the problem at hand in the pipeline industry. Pipeline operators use new technologies in their rhetorics to assure stakeholders that pipelines are safe. This greenwashing strategy is widely shared in the industry, indicating that in this context industry level actors are also involved. The chapter uses discourse analysis to show the presence of greenwashing as a strategy across the two levels of organizations and the industry. An encompassing quantitative analysis which employs Topic Modeling to process text data (Hannigan et al. 2019) then reveals how greenwashing spreads across the industry through intra-industrial networks. Finally, in the discussion section the chapter introduces the notion of technology as a vehicle for greenwashing.

Context and Data

The empirical sections of this dissertation use data on the US pipeline industry. This empirical context offers a number of advantages over other datasets on environmental emissions and pollution. Compared to other industries, there is a good data coverage on pipeline spill from a diverse group of actors, including government agencies, the press, grassroot organizations, and industry level organizations. The documents on spills often include information on the events as well as causes. Further, the pipeline industry allows us to "zoom" in and out on individual oil spills and understand environmental pollution and impacts in a much more thorough fashion than is the case for other industries. Longitudinal quantitative data over a relatively long time frame is publicly available.

Overall, pipeline spills as well as the subsequent learning process, and greenwashing attempts all play out in a public fashion.

Compared to environmental emissions and pollution by other industries, pipeline spills play out in a very public fashion. Pipeline spills are often initially discovered by members of the public (Shaw et al. 2012, p. 3-39). Pipelines are built across the country, often on public land. Hence, large pipeline spills cannot rarely if ever be fully concealed from the public. Large oil spills also make up for a dominant share of the overall spill volume, hence even if some small spills are missed the data still offers an almost complete picture. When oil enters waterways, its color and smell makes the spill very obvious. Pipeline operators and employees are legally obligated to report pipeline spills.[4]

There are two main sources for data on pipeline spills in the US. (1) The Pipeline and Hazardous Materials Safety Administration (PHMSA) maintains a repository on all pipeline spills that occur. A fairly unique attribute of the data is that there is both qualitative and quantitative data available. Over 300 pipeline spills occur in the United States every year, and more than 100 of them are classified by the PHMSA as significant.[5] The number of spills is sufficient for quantitative analysis to be sensible, but not at a level where an individual large spill becomes irrelevant. PHMSA also provides a dataset on pipeline operators, which allows for identification of the organization that caused each oil spills, how many miles of pipelines these organizational operate, and how much oil the organization transported over what distance each year.[6]. Between 2002 and 2004, PHMSA significantly increased the amount of data collected from each operator and on each spill. Hence, from 2004 forward the quality of the PHMSA data is generally good.

(2) The National Transportation Safety Board (NTSB) provides reports on pipeline

[4] See `https://www.phmsa.dot.gov/incident-reporting`, accessed 2020-08-30.

[5] Meaning an injury, fire, explosion or property damage of over $50,000, or the spill volume is at least 50bbls. See also `https://www.phmsa.dot.gov/sites/phmsa.dot.gov/files/docs/pdmpublic_incident_page_allrpt.pdf` and `https://julianbarg.shinyapps.io/incident_dashboard/`, accessed 2020-07-14.

[6] See `https://github.com/julianbarg/oildata`, accessed 2020-07-14

spills that the agency deems significant. These reports typically have a length of 50-200 pages (usually being more than 100 pages long) and detail the incident, events leading up to it, and its causes. From 1969 until today, 142 reports and briefs have been published. The NTSB reports stand out from other reports because of the NTSB's "Go Team". Members of the Go Team are ready around the clock to be deployed to accident sites, for the benefit of collecting information that might otherwise not be available anymore.[7] The NTSB also spends significant resources to determine underlying causes of (rather than liability for) the spills after the fact.[8]

In addition, other public agencies also sometimes become involved in th cleanup of pipeline spills and subsequently author reports. In addition to the quantitative data it provides, the PHMSA also occasionally commissions reports on pipeline safety (Shaw et al. 2012, e.g.,). Other agencies that are involved with pipeline spills and provide relevant information are the Environmental Protection Agency (EPA), the National Oceanic and Atmospheric Administration (NOAA), Fire Marshals, and the coast guard. All these agencies sometimes provide primary data on the impacts of pipeline spills.[9]. Journalists also report on pipeline spills, and sometimes create very in-depth material that represents a valuable addition to government reports (e.g., McGowan, Song, & Hasemyer 2012). Finally, residents that are affected by pipeline spills sometimes organization in grassroot organizations. These grassroot organizations provide valuable data on the human impacts of pipeline spills.[10].

[7] See `https://www.ntsb.gov/investigations/process/Pages/default.aspx`, accessed 2020-08-31.

[8] For instance, in one case NTSB tried to replicate an error of a SCADA system on a replica of the original SCADA setup (NTSB 2002), and in another case NTSB used various pieces of heavy equipment on a pipeline section to determine what caused the mechanical damages that lead to a spill (NTSB 1990).

[9] E.g., `https://response.restoration.noaa.gov/about/media/10-years-after-being-hit-hurricane-katrina-seeing-oiled-marsh-center-experiment-oil-clea`, accessed 2020-08-30

[10] E.g., `http://grangehallpress.com/Enbridgeblog/`, accessed 2020-08-30

Literatures

Multiple literatures contribute to this dissertation, the obvious ones being *organizational learning* and *greenwashing*. The learning literature further falls into two camps: *organizational knowledge* and *organizational routines* (Bingham & Eisenhardt 2011). Other literatures that inform this dissertation include the work on ESG indicators and *grand challenges*. Most importantly, there is an emerging stream in management research that discusses the management of natural resources (George, Schillebeeckx, & Liak 2015). This research stream's starting point is the observation that an excess emission of certain pollutants on a global scale would have catastrophic consequences (Rockström et al. 2009b), and the literature problematizes excess resource use.

Grand challenges and ESG indicators

The starting point for this work is the environmental part of the triple bottom line (Elkington 1997). To just mention one in a long lineage of conceptualizations (Bansal & Song 2017): Rockström et al. (2009a) argue that there are certain biogeochemical flows on earth, the condition of which constitutes a *safe operating space*. Based on these, one can define quantitative *planetary boundaries* for resource use. For instance, an ocean acidity above a certain value would lead to catastrophic results. This, and similar concrete environmental concerns have also entered management research (e.g., Whiteman, Walker, & Perego 2013). The social-ecological systems literature contends that to respond to these and other environmental concerns would require a rather unprecedented collective response (Reyers, Folke, Moore, Biggs, & Galaz 2018).

In addressing to environmental concerns and the difficulty of responding to them, AMJ initiated a Special Research Forum to motivate more work under the banner of *grand challenges* (George, Howard-Grenville, Joshi, & Tihanyi 2016). Usually, the grand challenges literature showcases or theorizes how organizations can defy limitations and effectively tackle grand challenges against all odds (e.g., Ferraro, Etzion, & Gehman 2015).

This dissertation turns the research on grand challenges on its head by taking as its starting point the status quo of pollution and improvements thereof–in a sense, the second order function of pollution. I pick an empirical context and investigate what emissions there are and what we can expect of the future. In that specific

The "gold standard" for research on environmental sustainability is to comprehensively measure environmental impacts. A common approach for doing so is to use an *ESG* indicator (Montiel & Delgado-Ceballos 2014). However, many barriers have to be overcome to make effective use of ESG indicators. Specifically, how the indicator is constructed has to be taken into consideration: the researcher has to be aware that the indicator is a product of social construction and has to treat it as such when conducting empirical research (Eccles, Lee, & Stroehle 2019). In particular, comparisons across industries are problematic. ESG indicators are always a combination of other metrics, and when for instance one of these metrics dominates the impact of an industry (e.g., downstream emissions of the fossil fuel industry), that should be taken into consideration during research design. Data availability also tends to be better for large corporations, favoring a cross-industry approach over intra-industry tests.

This dissertation sidesteps the issues associated with using an ESG indicator to some degree by using a more specific indicators that captures environmental pollution specifically. Moving from an ESG indicator to a more specific variable means making a sacrifice. The researcher at least to some degree forgoes the aspiration to measure impacts comprehensively, and research may become susceptible to greenwashing. For example, a chemical producer might try to improve its image by improving worker conditions; to then make any generalized statements on the sustainability of the corporation's operations without also taking into account e.g., environmental emissions would draw a wrong picture. On the flip side, to judge chemical company with excessive deaths only by its environmental impacts would also be flawed. By focusing on just one issue these complexities are lost.

The only context where focusing on just one metric would be justified is when that metric represents the most important area of impact. Coal power plants for instance are characterized by the high number of respiratory problems and indirect deaths they cause through air pollution, and the nuclear industry by its catastrophic potential. For pipelines, the case is less clear, because of their role in the fossil fuel supply chain, and by extension global climate change. However, pipelines are not indispensable for the global fossil fuel. A large share of petroleum transport globally happens by ship, which is also very cost-efficient. Thus, the pipeline industry's environmental impact is largely characterized by pipeline spills, especially because of their catastrophic potential.

Organizational learning

As mentioned above, the literature on organizational learning traces its roots back to two distinct streams of literature that can be distinguished by their definitions of learning. The first stream defines learning as "a change in the organization's knowledge that occurs as a function of experience" (Argote & Miron-Spektor 2011, p. 1124). Henceforth, this stream will be called the knowledge-based approach. The second literature holds that organizations learn "by encoding inferences from history into routines that guide behavior" ("Organizational Learning" 1988, p. 320). The contributors are much more careful about stating that organizations *know* per se the lessons learned. Henceforth, this second stream of literature will be called the behavioral approach.

Knowledge-based approach. The first discussions of organizational learning are found in the learning curve literature (Wright 1936). In particular, WW2 provided a couple of "quasi-experiments". In the shipbuilding industry, the researchers could observe how with every subsequent unit of production, productivity would improve (Searle & Gody 1945). The most straightforward mathematical representation of the learning curve is the progress ratio. For instance, if the progress ratio is p, then each time the cumulative output doubles, the unit cost would be predicted to drop to $p\%$ of its previous value (Argote 2013b, p. 15). In other words, while in the beginning organizational learning allows for a quick reduction of unit cost, eventually, the next doubling of cumulative production is so far out that the unit cost is almost constant. One ambition of the learning curve literature is to mathematically disaggregate learning curves into multiple intraorganizational factors that predict the speed of learning (e.g., Arrow 1962).

Because so many different factors were found to influence the learning rate, the literature eventually directed its attention to the process of organizational learning itself. A large share of this body of work roughly follows this pattern as exemplified by the structure of Love, Roper, and Vahter (2014): the author selects an organization-level performance variable (innovation, measured as sales from newly introduced products), and gathers this data for large companies in an industry or country (Ireland). Then, independent variables are selected that account for the heterogeneity across organizations (innovation linkages, measured as product development with customers or suppliers, joint ventures, etc.). This approach has allowed researchers to identify a broad variety of sources of variation (Argote 2013b, pp. 18ff).

A limitation of this relatively formulaic approach however is that it may fail to identify path-breaking innovation. Not all knowledge is equally important, and the best insights are sometimes difficult to capture with quantitative metrics. For instance, some new pieces of knowledge might fall outside the regular schema of innovation and lead an organization into a new industry. And many fossil fuel companies are currently (still) successful because they double down on their existing knowledge stock and insulate their industry from changes–an orthodox learning paper might still diagnose learning, if, for example, production increases. But an example of a more interesting question with regard to learning would be which organizations manage to diversify and benefit from the rise of renewable energy.

Behavioral approach. The Carnegie school early on took notice of organizational learning (e.g., Cyert & March 1963). For some time, this literature developed in parallel to the learning curve literature. This difference between the two approaches is best exemplified by Argyris and Schön (1978). Argyris and Schön (1978) developed the concept of double-loop learning. The first loop represents adjustments according to well-known decision criteria, such as launching a promotion when a sales goal is not met. The second loop represents an adjustment of the decision making process itself. For instance, a member of the organization may discover that the organization's goal has become unattainable, and push for a modification of the goal itself. This literature allows scholars to talk about issues that fall outside the scope of the learning curve (and knowledge-based) literature. A drawback is that it is difficult to translate the this literature into empirical work. For example, one major criticism of learning curves is that findings may have resulted from a self-fulfilling prophecy–an organization ends up at a certain productivity level *because* that productivity level was the goal. The organization would not overaccomplish, because members lower their efforts when they approach the target. And if the organization falls short of its goal, the organization may move the goal post–by adjusting the goal, or its accounting approach.[11] The behavioral approach provides us with a language to discuss these issue and similar issues.

Concepts that speak to the phenomenon of pipeline spills include the aforementioned double-loop learning, exploration and exploitation (March 1991), the competency trap ("Organizational Learning" 1988), and experiential learning under ambiguity (**?**). Some streams of the behavioral approach have cross-fertilized the knowledge-based stream. These include work on learning from rare events (March, Sproull, & Tamuz 1991, Maslach, Branzei, Rerup, & Zbaracki 2018), and learning from failure (e.g., Madsen & Desai 2010). These literature talk to some of the tensions that can be observed with regard to pipeline safety–an insistence on existing technology, and a lack of major overhauls, but also surges in activity in response to spills.

[11] Similarly, the reason why organiztional learning and learning curves appear to be omnipresent could be a result of a publication bias.

Greenwashing

Greenwashing describes a range of activities. This section provides three examples of greenwashing. This dissertation uses the third one, selective disclosure, which should be distinguished from the first two. The first, maybe the oldest one, describes an attempt of improving reputation through association with a signifier of ethics. For instance, "bluewashing" describes a corporation's effort to construe an association between a product and the United Nations (Laufer 2003). Similarly, in marketing greenwashing describes falsely advertising a product as environmentally friendly (Delmas & Burbano 2011). For that purpose, a corporation does not necessarily need to make false claim. It may be sufficient to use green packaging and images of flowers. Many consumers can also be mislead with close-to-meaningless labels and certifications. Greenwashing has also long been a problem at the level of corporate governance (Ramus & Montiel 2005). With regard to environmental reporting, the term greenwashing as used in the literature often describes a process of selectively releasing positive information about one's environmental (or social) performance without also releasing negatives ones (Lyon & Maxwell 2011). That approach of selective disclosure is insidious, because the information released are objectively true, yet, the picture of reality they paint is not accurate. The approach is also suitable for empirical research on organizations. Marquis, Toffel, and Zhou (2016) for instance operationalizes greenwashing as the difference between what share of metrics of environmental performance a corporation discloses and what share of total impacts these disclosed emissions make up for. For example, a corporation that discloses nine out of ten of its emission types, but where the missing emission type makes up for 90% of its environmental impacts, would gain an abysmal score of $0.1 - 0.9 = -0.8$.

The abovementioned types of greenwashing have in common that none of the statements which organizations make are openly untrue, or even criminally liable. Note also that intent is not a necessary condition for greenwashing (although intent is often implied). For instance, Lyon and Maxwell (2011) point out that a firm might itself be uncertain of its environmental impacts (Lyon & Maxwell 2011, pp. 26f). More universally, greenwashing can be defined as "any communication that misleads people into adopting overly positive beliefs about an organization’s environmental performance" (Lyon & Montgomery 2015, p. 225). Within that definition, greenwashing takes on different forms. Since misleading communication constitutes greenwashing regardless of intent, a discussion of motivations and mechanisms for greenwashing is optional in empirical works on the topic. That definition of greenwashing as misleading communication regardless of intent describes well the developments taking place in the pipeline industry. Although the qualitative data provides several examples that suggest malicious intent, the divergence between asserted and observed pipeline safety to some degree resides at the industry level and is shared by all actors. The myth of pipelines as a safe technology is diffused at the population level by actors such as the American Petroleum Institute, the engineering profession, and shared technologies. The qualitative data allows us to make educated guesses as to the mechanisms at play at the different levels, but not to establish unambiguous intent and effect direction.

The divergence between communicated and observed pipeline safety amounts to more than just a decoupling process. The diffusion of pipeline technology ensures some coupling in the industry, and there is little evidence that technology is used throughout the industry in ways that it is not intended for. Decoupling does not equal greenwashing (Lyon & Montgomery 2015). For example, if sustainability is decoupled in an organization because the sustainability does not have sufficient resources to effectively implement initiatives, and the organization then announces a major initiative, this communication would then qualify as greenwashing. However, not all decoupled activities result specifically in greenwashing, and not all cases of greenwashing are the result of decoupling–as mentioned above, greenwashing can also be a deliberate, malicious strategy. Decoupling could occur in other areas, such as R&D activities, and greenwashing could result from other organizational processes, for example malice or misjudgment. This dissertation specifically discusses greenwashing that results from a technology that may function as designed, but does not deliver the results that it promises. Motives for greenwashing in this context vary. There are documents that are specifically written to testify that pipelines are safe to obtain permits (e.g., discussed in Stansbury 2011). But there are also grey areas, where financial interests and obligations to ensure pipeline safety are interweaved and cannot be disentangled. Decoupling certainly is not the encompassing or even dominant cause of cause of greenwashing in the pipeline industry.

Chapter 1: Stuck on Innovation

Organizational learning comes down to choices. Firms can either invest in improving existing technology, or develop new technology (March 1991). Investing in the "wrong" technology can lead to technological lock-ins (Levinthal & March 1993). The actors in the pipeline industry have selected a number of technological solutions to resolve their most pressing issue. When a pipeline spill occurs, the oil quickly infiltrates the soil and seeps into the groundwater.[12] The environmental degradation caused by oil affects the local environment, and the local populace, too: a 2019 sibling comparison study on oil spills in Nigeria found that in localities that are affected by oil spills, for every 1,000 live births, an additional 38.3 neonatal deaths occur(Bruederle & Hodler 2019).

In their fight against pipeline spills, pipeline operators employ a variety of technologies, such as smart pigs, leak detection systems, and SCADA systems. Smart pigs, while traveling through the pipes, utilize electromagnetic flux or ultrasonic probing to assess corrosion or mechanical damages to the pipe (Singh 2017). Internal leak detection systems measure the flow of oil at two points A and B to detect any loss in between those points. External leak detection systems detect signs of escaping hydrocarbons, and include acoustic, hydrocarbon, and temperature sensors. (Shaw et al. 2012). SCADA systems are systems that allow an operator remotely monitor and operate lines. The operator typically

[12] The infiltration depth in sand is assumed to be over 10m in the first day alone (Bonvicini, Antonioni, Morra, & Cozzani 2015).

sees on his screen charts of the flow at different points, can open and close valves, and startup or shutdown delivery of oil. Alarms from leak detection systems of the line are also displayed to the SCADA operator.[13]

The high technology character of leak detection stands in contrast to the experienced reality of pipeline spills. A 2012 study commissioned by the Pipeline and Hazardous Materials Safety Administration (PHMSA) of onshore pipeline spills that occurred over a 19 month period, SCADA systems assisted in less than 25% of cases with the detection and confirmation of the spill (Shaw et al. 2012, p. 3-33). In only 17% of cases was the operator or SCADA system listed as the initial identifier of the leak, while the public or emergency responders identified 30% of leaks (Shaw et al. 2012, p. 3-39). Why do the great learning efforts by pipeline operators fail to deliver the safety improvements that one would expect to see? A 2012 report prepared by the National Transportation Safety Board (NTSB) on the Kalamazoo River oil spill provides a good starting point for understanding the problem. A regional manager of Enbridge is quotes as saying: "...I'm not convinced [that there is a problem]. We haven't had any phone calls. I mean it's perfect weather out here–if it's a rupture someone's going to notice that, you know and smell it" (NTSB 2012, p. 100).

This chapter uses the quantitative data from PHMSA to demonstrate how existing problems are addressed, following major spills that catch the attention of the industry, the regulator, and the public. That empirical observation is contrasted with the character of the two challenges that remain: (1) as holes are plugged, new unique sources of spills, for example climate change-related weather changes, emerge. (2) Both the "human factor" and the "organizational factor" are pervasive factors that yet to be completely eliminate as sources of error in any context. Overall, the geographic, technological, and organizational complexity of pipelines have led to the current situation, a quasi-standstill in the sector for

[13] Larger pipeline companies operate control centers where all lines in a region are managed. Operators usually operate multiple SCADA systems at once, and more experienced employees supervise the operators. Control centers are operated in formal hierarchy, where for certain operations (such as clearing an alarm), a SCADA operator will require the go-ahead from a supervisor. See NTSB (2012) for an in-depth description of an Enbridge control center in Edmonton as of 2012.

refined oil. Crude oil pipelines on the other hand still have some potential for improvements, as simple and fundamental problem of this sector– the corrosiveness of the commodity– is addressed through new coatings, and cathodic protection.

The quantitative section of this chapter uses a sample consisting of the 100 largest operators in the pipeline industry over the period from 2004 through 2019. The data that is available from PHMSA is matched and supplemented with data from Compustat. This quantitative section focuses on improvements over time in organizations affected by a specific source of incidents, and a reduction in certain causes of spills. Some qualitative data supplements the quantitative analysis by showcasing the processes of population level learning (Miner & Anderson 1999), especially for crude pipelines. The qualitative section then uses archival data to explore a sample of 15 major pipeline spills since 1986 to contrast the specificity of learning in the quantitative analysis with the complexity of the systems that the incidents occur in, and the complex interactions that lead to spills. The sample of 15 spills includes the top three spills with regard to spill volume, net loss (spill volume minus volume recovered), number of injuries, number of fatalities, and property damage. This sampling method ensure both a variety in the type of spills, and a good availability of archival data.

This chapter contributes to the literature on knowledge-based learning by exploring the topic of a bottomed-out learning curve through raising the issue of aggregate and specific learning. The chapter also contributes to the debate on industry resource use: it discusses both the historical development and the potential future reduction (or lack thereof) of an industry's environmental footprint. Whereas in the past, improvements were made through incremental learning in the form of development of new technology, the analysis suggest that further improvements may only be possible through bold, maybe costly new choices, including a change of industry for some companies.

Chapter 2: Theoretical Foundations of Learning

This literature review focuses on organizational learning. The purpose of this chapter is to shed light on the intricacies of learning in the pipeline industry from a theoretical perspective. The first section summarizes the literature of the *organizational knowledge* approach. In particular, the section emphasizes the strength of the knowledge-based approach, which accurately describes the accumulation of a knowledge stock that does take place in an organization when the goal is more or less clear and the environment stable. Further, This first section summarizes some of the other accomplishments of the literature that roughly fall into the knowledge-based stream, specifically its predecessor the learning curve literature, as well as vicarious learning, and population level learning.

The second section summarizes the *organizational routines* view of organizational learning. In particular, this section highlights the gaps left by the knowledge-based approach that may be filled by work in the behavioral space. The behavioral approach appreciates the nonlinearity and messiness of learning. Significant learning can results from individuals or groups organization that seek for the organization to break with convention (Argyris & Schön 1978). This form of learning poses a challenge to the knowledge-based literature, because the changes that take place fall outside the normal rubric of improvement (as exemplified by learning curves). Other examples of these qualitatively different dimensions of learning in the literature are exploration and exploitation (March 1991), and high intellect vs. low intellect learning (March 2010).

Chapter 3: The Green Black Gold Blues. Diffusion of greenwashing in the pipeline industry

> ’[W]e are building a pipeline that is state of the art and will be the safest pipeline ever build.’ – TransCanada President & CEO Russ Gerling on the Keystone Pipeline[14]

[14] `https://youtu.be/ctx0H8XR51s?t=127`, accessed 2020-08-23.

> Although pipeline technology has improved, new pipelines are subject to proportionally higher stress as companies use this improved technology to maximize pumping rates through increases in operational pressures and temperatures, rather than to use this improved technology to enhance safety margins. – Excerpt from a technical report that challenges the environmental impact assessment for the Keystone Pipeline (Stansbury 2011, p. 4)

For decades, activists have called out corporations for not walking the talk. In 1992, Greenpeace warned that the most powerful corporations' rhetorics mostly serve to distract the public, while these corporations fight off liability and accountability in the judiciary and legislative arena (Bruno 1992). To describe this phenomenon of corporations building a false green image, grassroot movements have coined the term "greenwash". Greenwashing describes "any communication that misleads people into adopting overly positive beliefs about an organization's environmental performance" (Lyon & Montgomery 2015, p. 225). Generally, corporate communication with stakeholders is driven by their goals and interests. For instance, what corporations stay quiet about is as important as or more important than what they do disclose (Kim & Lyon 2015). Hence, what corporations say cannot be taken at face value. The greenwashing literature researches this problem with regard to environmental performance. The most common style that has been explored in the literature is disclosure of only positive information on environmental performance and withholding of bad news (Lyon & Maxwell 2011). To date, research has focused on different types of greenwashing, their prevalence, and performance implications for corporations (Kassinis & Panayiotou 2018, Marquis et al. 2016, Ramus & Montiel 2005, Seele & Gatti 2017).

The existing research shows that greenwashing is a phenomenon that plays out not only at the level of individual organizations. In empirical research, to control for industry effects has become the norm (e.g., Du 2015, Marquis et al. 2016, Ramus & Montiel 2005, Testa, Miroshnychenko, Barontini, & Frey 2018). The necessity to control for the industry indicates that there are important processes taking place within industries. Standards and research insights that are shared across an industry can act as templates for greenwashing, and organizations copy each other's greenwashing strategies. The greenwashing literature has yet to cover these processes. Under the watchful eye of stakeholders, entire industries such as mining, agriculture, or the energy sector have come under suspicion across the board and need to constantly put in efforts to legitimize their business models. In cases such as these, industry could even surpass organizational factors as a predictor for greenwashing. Hence, a discussion is overdue on the question: *How does the industry affect organization's propensity to greenwash?*. Assisting with this question can other literature on inter-industry processes (such as Hardy & Maguire 2020, Maguire & Hardy 2009).

To empirically demonstrate how industry-specific greenwashing strategies are diffused, this research turns to an industry where greenwashing has taken a very peculiar form. The pipeline industry uses the veil of engineering to present itself as safe, and pipeline technology as perfectly controllable, despite pipeline spills being a regular occurrence in the US. The public repository of the Pipeline and Hazardous Materials Safety Administration (PHMSA) holds data on both individual operators' pipeline miles and the volume of crude and refined petroleum transported. Further, the repository offers a description of and quantitative data on each minor and significant pipeline spills that has occurred in the US. The analysis of text data for this research relies on Natural Language Processing (NLP)–specifically, Topic Modeling–to determine spill causes and technology trends (Hannigan et al. 2019). The descriptions of individual spills reveal the shortcomings that individual operators exhibit in terms of pipeline safety. This data is matched with text data on pipeline safety strategy obtained from annual reports or, where available, safety reports. Annual or safety reports provide insight into the strategic plans and actions of operators. Next, data on headquarter location and executives' connections (BoardEx) surfaces networks within the industry. Finally, documents by industry-level actors such as the American Petroleum Institute (API) or the PHMSA unearth the latest industry trends.

Greenwashing is given where non-substantive industry trends, rather than the operator's safety problems, determine individual operators strategic plans and action. By using operators' spill frequency and volume over time, we can ensure that effective measures are not accidentally flagged as non-substantive.

By researching greenwashing in the pipeline industry in the form of non-sustantive strategic plans and actions in the pipeline industry, this research expands the greenwashing literature. The empirical data reveals the flow of information within the industry, and the contribution of intra-industry networks to greenwashing. Greenwashing in the form of engineering and technology-centric communication also represents an addition to the literature. This form of greenwashing is particularly insidious, because an observer needs to first penetrate a layer of engineering and technology lingo, before the underlying issue can be surfaced. The addition of this form of greenwashing to the literature could help direct attention to other industries that have developed sophisticated forms of greenwashing which may be impossible for laymen to discern. Polluting industries that make intense use of new technologies are likely candidates to exhibit this form of greenwashing, for example chemistry, engineering, and construction. Exposing the role of industry-level actors such as the API, and an industry-wide propensity to greenwash also has relevance outside academic circles. Where the industry plays a role in greenwashing, policy makers and activists that seek to reign in greenwashing need to take a more systemic view, and target industry-level actors, or industries as a whole. On a related note, this unique cross-level research, which spans from the industry down to individual spills, also contributes to the literature on social-ecological systems (Reyers et al. 2018).[15]

[15] More recently, the need for cross-level research has also been voiced repeatedly during the ARCS Online Seminar Series and Ivey Sustainability Salon. For instance, at the Ivey Sustainability Saloon session on July 16, 2020, Tima Bansal to Nicholas Poggioli: "If the firm is at one level, one could argue that the eco-system is a different level in which many actors interact. And, arguably, Sustainable Development is a macro-level concept (system of actors)."

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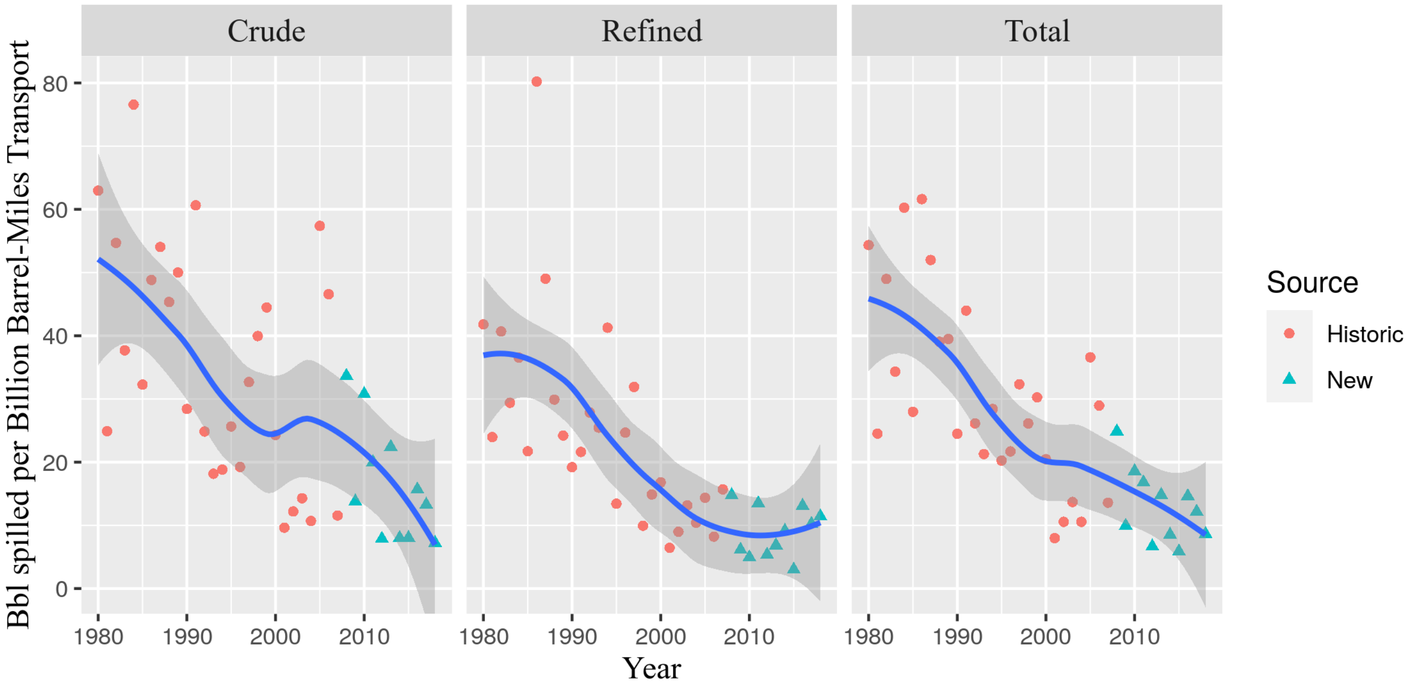
Figure 1. Pipeline safety improvements at the industry level



Blue line:	Local regression (Loess), with confidence interval.
Source (new):	https://github.com/julianbarg/oildata
Source (historic):	http://www.api.org/environment-health-and-safety/clean-water/oil-spill-prevention-and-response/~/media/93371EDFB94C4B4D9C6BBC766F0C4A40.ashx, p. 38