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Capacity expansion under regulatory uncertainty: A real options-based study in international container shipping

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ABSTRACT

We present a real options model for capacity expansion that introduces uncertainty about potential future regulation (regulatory uncertainty) and key characteristics of capacity decisions: investment with time to build, divestment, the option to charter, and operating flexibility. Regulatory uncertainty is modelled as a possible jump in operating, investment, and charter costs during the simulation horizon. We find that regulatory uncertainty *with* grandfathering (the extant fleet is exempt from compliance) promotes high up-front investment leading to excess capacity and increased emissions. However, regulatory uncertainty *without* grandfathering reduces investment and emissions and the use of more flexible capacity options, such as chartering.

1. Introduction

In the past, international maritime shipping has been largely excluded from environmental regulation efforts that forced other industries to reduce their ecological footprints. Although such shipping is the most ecologically friendly means of transport, the industry's sheer size makes it a major contributor to worldwide emissions and pollution with a total contribution of 3% to global CO_2, 13% of NO_x and 12% to SO_x emissions (International Maritime Organization, 2014). This fact has attracted the interest of such regulators as the International Maritime Organization (IMO), the European Union (EU), and the United States, thus the industry will increasingly be subject to regulation. With the target of reducing greenhouse gas emissions by 20% below 1990 levels by 2020 (Helfre and Boot, 2013), one such policy is the stepwise reduction of SO_x emission limits from 4.5% to 0.5% globally and even 0.1% in specially designated areas. Even before these new regulatory efforts, ship investors and operators faced an investment decision complicated by its high capital intensity and by several sources of uncertainty, such as volatility in charter and freight rates. Regulator actions introduce a new risk, and firms must account for both the content and timing of prospective regulation. The main reason for timing uncertainty is the process by which the IMO, as a representative of seafaring nations within the United Nations, passes new legislation: no new convention is in effect until enough member states have ratified it. Because that process can be a lengthy one, there is uncertainty about the exact content and timing of future regulation.

Given their effect on operational costs, regulations (and their associated uncertainty) must be considered when evaluating any opportunity owing to their influence on investment success (May, 2011). Traditional discounted cash flow (DCF) valuation methods are not well suited to capture uncertainties and stochasticity (Dixit and Pindyck, 1994); in contrast, real options models can be successfully used to analyze the effect of regulatory uncertainty.

This paper presents a real options model for precisely that purpose. In a numerical study, we investigate the effects of uncertain regulation by applying our model to the container shipping industry. We also assess whether there is a significant difference between expected regulatory action that allows for the so-called grandfathering of current capacity and regulation that affects all ships (i.e.,

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regardless of when purchased). For that purpose, we formulate a real options investment model in a dynamic programming (DP) framework. Thus we extend the capacity investment model of Fontes (2008) by introducing time to build, adding an option to charter, and incorporating regulatory uncertainty. Finally, we use approximate dynamic programming (ADP) to solve this computationally intensive model and to overcome the "curses of dimensionality" (Powell, 2011) in real-world–sized instances.

Our paper contributes to research in four ways. First, we extend the methodological literature by proposing an approach to consider regulatory uncertainty via an investment model applicable to many industries. Second, we employ a novel ADP variation that approximates the additional value created by investment—that is, above the lower boundary established by a strictly myopic strategy. Third, by fitting our model to the shipping industry, we contribute to research on shipping through the insights we derive on optimal decisions—from the investor's perspective—under regulatory uncertainty. Fourth, though we do not focus on optimal policy making from the viewpoint of a regulator, we do help regulators better understand how legislative processes that induce uncertainty affect the investment decisions of market participants and resulting industry emissions.

The rest of the paper proceeds as follows. Section 2 reviews the existing literature on real options in general and in the shipping industry; it also introduces the existing literature on regulatory uncertainty. In Section 3, we use DP to develop a formal real options model for regulation with or without grandfathering. Section 4 introduces our ADP approach to solving the computationally intractable DP model. In Section 5, this latter method is used to present our findings from a numerical study tailored to the container shipping industry. Section 6 concludes.

2. Literature review

Uncertainty can be defined as "perceived inability to predict" an organization's future external environment (Milliken, 1987). We adopt that definition and focus on state uncertainty, where the organizational environment's future states are uncertain owing to, for example, unforeseeable regulatory action. Uncertainty due to emerging eco-regulation is acknowledged to be a growing concern for businesses in many industries (Marcus et al., 2011). While Lister et al. (2015) find that maritime shipping is lagging behind in terms of reducing its environmental footprint, both Lister et al. (2015) and Poulsen et al. (2016) detect significant regulatory uncertainty regarding content and timing of upcoming regulation as the IMO is accelerating its regulatory efforts. For example, IMO regulations require member ratification—a lengthy process that can last "a decade or longer" and so is clearly problematic for shippers' investment decisions (Lister et al., 2015). May (2011) expects regulatory uncertainty, and its adverse effect on investment decisions, to be one of the industry's key future challenges. The IMO has discussed (and, in many cases, implemented) ecological measures that target energy efficiency in ship design and operational procedures, ship recycling, ballast water management, and ship exhaust emissions of carbon dioxide, sulfur, and particulate matter. While regulation in other sectors such as power generation mostly allows the grandfathering of previously existing capacity, this is not always the case in shipping. While, for example, requirements for energy efficient ship design only target newly built vessels, lower sulfur emission levels or the requirement to develop operational measures for increased fuel efficiency are mandatory for both new and existing ships. (International Maritime Organization, 2016a).

Research on the effects of regulatory uncertainty has mainly focused on whether or not it leads to a deferral of investment. A majority of researchers has argued that investment is dampened: Reinelt and Keith (2007), for example, model replacement decisions for coal-fired power plants. They account for the introduction of regulation as a stochastic increase of carbon emission costs where both timing and the new cost level are uncertain. They find that such uncertainty increases social costs of abatement and dampens investment incentives if abatement options are expensive. Similarly Fuss et al. (2009) analyze capacity investment in the energy sector under regulatory uncertainty represented by stochastic carbon emission prices. They also find that increased volatility in emission prices defers the adoption of less emission intensive but more expensive technologies. Providing regulatory certainty is also demanded by Blyth et al. (2007), who find in their real option model for the energy sector that this would incentivize adoption of low carbon technologies. Ritzenhofen and Spinler (2016) find deferred or even withdrawn capacity investment in a real options framework if feed-in tariff support schemes are withdrawn, creating regulatory uncertainty. Several empirical studies also support the view that investment is deferred by such uncertainty. Fabrizio (2013) finds reduced investment incentives in the US renewable energy sector in states with greater uncertainty. Similarly, Gulen and Ion (2016) show the same in an empirical study across multiple US industries.

Opposing views are held by Hoffmann et al. (2009), who use a resource-based view of the firm to argue that regulatory uncertainty can promote investment, if it can be used to build up a competitive advantage or alleviate societal pressure. From a real options perspective, Hassett and Metcalf (1999) find that if uncertain tax policy is modelled as a discrete jump process (which is more realistic than a continuous time random walk), investment is carried out earlier with more capital invested. Boomsma et al. (2012) focus on the energy sector and find both effects: uncertainty regarding the potential change of support schemes leads to investment deferral, while uncertainty from renewable certificate trading leads to the opposite effect. Baumann and Friehe (2012) find in an options model that uncertainty from potential market liberalization can increase incentives for market entry but reduces investment by incumbent players.

Adopting a similar approach to model regulatory uncertainty as Reinelt and Keith (2007), we extend research on investment under regulatory uncertainty to the maritime shipping industry. We will also show that, whether such uncertainty has positive or negative effects on investment crucially depends on the policy's design: in our case whether or not regulation allows grandfathering of old capacities is pivotal.

Real options methods are well suited to value investment under various uncertainties. While Dixit and Pindyck (1994) give an invaluable overview of methods available, there are several contributions that feature model characteristics also relevant to our model: Bar-Ilan and Strange (1996) are credited with introducing investment *lags* (or time to build) that we also consider; both