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Economic consequences of and resilience to a disruption of petroleum trade: The role of seaports in U.S. energy security

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ABSTRACT

Despite increased domestic production, the U.S. is still importing more than one-third of its crude oil needs, the vast majority via ocean tankers. At the same time, there are increasing concerns about the vulnerability of ports and terminals to man-made and natural disasters. This paper advances a methodology for estimating the total economic consequences of and resilience to a disruption of crude oil and refined petroleum product trade at a major seaport. The methodology is able to estimate not only the direct impacts of such disruptions but also the supply-chain effects. It also estimates the effects of muting the impacts by various resilience tactics such as ship re-routing, drawing inventories from storage, accessing the Strategic Petroleum Reserve, geographic shifting of petroleum refining, and production rescheduling. We apply the methodology to a 90-day disruption of petroleum trade at the twin seaports of Beaumont and Port Arthur, Texas. The results indicate that port region and national economic activity could decline by billions of dollars, but that resilience can reduce these consequences significantly. We also conclude that factors associated with the recent surge in the extraction of shale and tight oil resources has significantly enhanced the potential effectiveness of some resilience tactics.

1. Introduction

Most studies of energy security focus on a nation's vulnerability to supply shortages, and some studies address strategies to reduce it. The analyses typically focus on geopolitical crises as the major source of disruptions. Studies on reducing vulnerability have nearly always emphasized pre-disruption mitigation, i.e., ways to reduce the frequency and magnitude of disruptions in the first place. Thus, most studies to date overlook two key considerations. The first pertains to vulnerabilities of regions, delineated by the ports and the areas surrounding them that are dependent on trade, within large countries such as the U.S. The second pertains to reducing vulnerability by post-disruption resilience, i.e., ways to dampen economic consequences by various tactics that utilize existing resources more efficiently after the disruption has begun.

A major example of an energy security issue is the disruption of a seaport that is the unloading point for tankers carrying both imported and domestic crude oil and refined oil products, as well as serving as the loading point for exports of these same commodities. The impact of the disruption quickly ripples through the regional economy, first by disrupting the key input into downstream petroleum processing operations located near the ports, such as oil refineries and chemical manufacturers, or affecting business consumers and residential customers of refined petroleum products. Disruptions of such ports can have further ripple effects down-stream in the supply-chain by causing shortages of goods that directly and indirectly use raw or refined petroleum products. Furthermore, upstream ripple effects will emanate from the inability to ship exported crude oil or refined products. Two example potentially strategic ports are the Port Arthur/Port Beaumont petrochemical complex, which produces approximately 22 percent of the refined oil and 9 percent of chemicals produced in Texas and 6.7 percent of refined oil and 1.3 percent of chemicals produced in the U.S., and the Port of Providence, Rhode Island, which is the point of embarkation for the majority of the heating oil used in the New England states.

Seaports are considered prime terrorist targets and are a major example of critical infrastructure that has been given priority by the US Department of Homeland Security. In addition to terrorist attacks, disruptions can be caused by technological accidents and natural disasters, not just at the port site but also as a ramification of damage to nearby offshore drilling platforms or pipeline breakages, and ship accidents, as well as destruction of transportation arteries that are used to

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transport goods from the ports to inland locations.

Many recent studies have estimated the economic consequences of port disruptions following labor strikes, technological accidents and simulated or actual natural disasters (Park et al., 2008; Rose and Wei, 2013; Rose et al., 2016; Wei et al., 2017). However, only studies by the authors have included consideration of major types of economic resilience. Our previous studies have indicated that these resilience tactics have the potential to reduce regional and national GDP and employment losses by more than 75%.

The purpose of this paper is to estimate the direct and indirect regional and national economic consequences of a 90-day disruption of petroleum trade at Port Arthur and Beaumont, Texas. These twin ports are surrounded by major oil refineries and petrochemical complexes. We use regional and national input-output models for the analysis, justifying their application even though this modeling approach is often not considered state-of-the-art. We explain how the major determinants of the bottom-line economic impacts are not the size of the standard multiplier or general equilibrium effects, but rather the extent of the efficacy of various resilience tactics, which can be effectively modeled by our methodology.

This paper advances the literature in several ways. It extends the authors' methodology for estimating the impacts of a port disruption in general and oil trade disruptions in particular. It also provides the most accurate estimates to date of likely resilient responses. Most importantly, it presents a reference point for assessing the regional and national vulnerability of a petroleum trade disruption. Our study finds that the disrupted regional economy is only likely to be minimally affected because of the offsetting influences of such resilient features as the existence of nearby ports and refinery complexes to where ships can be rerouted, excess capacity at those locations, the existence of inventories at Beaumont/Port Arthur and neighboring areas, and the ability to recapture lost production when import flows are restored. The impacts are even smaller at the national level in both absolute and relative terms, as oil extraction and refining are shifted to areas outside the directly impacted region. However, for some level of port activity or some locations, an oil import disruption would be significant, at least at the regional level, i.e., it could severely disrupt motor vehicle travel and strain heating supplies causing price spikes and/or shortages. The methodology presented here can be used to evaluate the vulnerability of other ports or combinations thereof.[2] This could significantly help improve resource allocation decisions regarding U.S. critical infrastructure. It raises the issue that all seaports may not really be "critical" to regional and national energy and economic security.

In Section 2, we present a brief review of the literature on the topic of seaport disruptions, with an emphasis on the implications for energy security. A background introduction of the U.S. and Gulf Coast Regional petroleum systems is presented in Section 3, together with a discussion of the role of the Port Arthur/Beaumont petroleum sectors in the regional and national economies. In Section 4 we present an overview of the modeling approach. In Section 5, we present a discussion of our measurement of resilience. In Section 6, we present our estimates of the regional and national impacts of the 90-day disruption at Port Arthur/Beaumont without the incorporation of resilience considerations. In Section 7, we present our estimates of these impacts with the inclusion of resilience. We conclude with a brief summary and discussion of future research.

2. Literature review

Energy security has been a prominent topic since the Arab Oil Embargo of 1973-74. Most of the research has been at the national level with a focus on vulnerability to oil imports. Major themes of this research are the calculation of macroeconomic impacts (Hamilton, 1983; Mork, 1989; Kilian, 2009), the estimation of an oil security premium (Brown and Huntington, 2013), and various strategies to deal with the disruptions, including increasing domestic supply, decreasing demand, and accessing the Strategic Petroleum Reserve (Bohi et al., 1993; Teisberg, 1981; Taylor and Van Doren, 2005). Aside from the SPR, the majority of the remedies are long-run in nature. Moreover, few studies other than those reviewed below have been undertaken at the regional level and even fewer have focused on short-term resilience strategies as we do here. Thus, our paper fills these two gaps in the literature.

Numerous studies have been undertaken of seaport disruptions. Increasingly, these studies have included downstream supply-side effects. However, most neglect the fact that the same port disruption will also reduce the flow of exports, a phenomenon that causes upstream supply-chain ripples. Also, few studies consider resilience in their assessment, and even fewer consider the broad range of resilience tactics. Even fewer studies have focused on petroleum trade disruptions. Below, we summarize literature focusing on more recent studies that have been relatively more comprehensive than earlier ones in terms of incorporating considerations of resilience. However, we do include some major studies that examine port disruptions dominated by petroleum trade and related activities.

Smythe (2013) assessed the impacts of Superstorm Sandy on the Ports of New York and New Jersey through interviews with victims of the disruption. The author found that cooperation between the public and private sectors, as well as the need for an increase in fuel reserves and personnel management, were greatly facilitated thanks to the formal port governance system. However, the loss of electricity, while temporarily handled by generators, led to a series of negative consequences, such as a loss of communication, security concerns, and the shutting down of oil terminals. The loss of petroleum product then exacerbated the situation not only in the port area, but also its surrounding communities. The author also highlighted the problems that arose from personnel that were evacuated from the area and those that did not have transportation to the port.

Rice and Trepte (2012) surveyed a number of port practitioners regarding different types of disruptions they experienced, as well as which processes and improvements would most lead to increased resiliency. They found that, while ports are generally successful in handling and quickly recovering from small, frequent disruptions (which are most common), most ports are much less resilient to large, extended disruptions. While the survey also found that there is no absolute consensus among port stakeholders on which actions are most important towards resilience of the port system, flexible labor agreements and improved communication and information services were the most desired measures based on the survey respondents' experience in small-scale port delays or disruptions.

Southworth et al. (2014) conducted case studies of the Ports of New York and New Jersey following Superstorm Sandy in addition to the closing of marine ports along the Columbia River in the Pacific Northwest due to the river system rehabilitation project. Following interviews with a number of experts involved with these events, the authors found that a successful communication and an uninterrupted flow of information are considered the most important factors in returning to a normal level of operation. The authors also highlighted several other actions that would assist in recovery including coordination with landside operators to divert cargo following a disaster, prioritizing incoming vessels by importance of assisting with recovery, and arranging on-site housing for critical staff, emergency responders, and relief workers.

Trepte and Rice (2014) analyzed the entire port system within the United States in order to estimate the capacity of the system to absorb the cargo from a disrupted port. This was done by identifying the commodity types and total volume that major ports take in as a baseline and then measuring how much capacity is needed to absorb

[2] In the case of significant price increases, further refinement of I-O methods need to be invoked. Also, the resilience analysis presented here is more generally applicable, such as its ability to be incorporated into CGE models (see, e.g., Rose et al., 2016).