Resource Booms and the Macroeconomy: The Case of U.S. Shale Oil

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Overview

Technological advances in horizontal drilling and hydraulic fracturing have led to an unprecedented increase in U.S. oil production. Often referred to as the shale revolution, the boom in U.S. oil production has renewed interest in the long-standing question on the link between resource booms and economic performance. There are several recent papers focusing on the local or regional implications of the U.S. shale boom, suggesting positive economic effects (see, for example, Feyrer et. Al (2017) and Allcott and Keniston (2018)). However, little is known about the implications of this boom for the U.S. aggregate economy and trade. In this paper, we study the importance and implications of the U.S. oil boom for the U.S. economy, trade balances, and the global oil market in a dynamic stochastic general equilibrium model of the world economy that takes into account unique characteristics of the U.S. experience: a large increase in production of a certain type of crude oil with an oil export ban in place.

The relatively few general equilibrium models that feature oil generally assume that oil is a homogenous good. This is a strong assumption since the characteristics of oil can differ across several dimensions, one of which is density. A key feature of the recent U.S. oil boom is that oil produced from shale deposits via the application of horizontal drilling and hydraulic fracturing is predominantly one type of oil: light crude. Different types of crude oil are imperfect substitutes for each other in the refining process and refining sectors tend to specialize in processing certain types of oil. The U.S. refining sector is specialized in processing heavier crude oils relative to the rest of the world. This mismatch of increased supply of light oil and existing refining capacity for heavier oil in the U.S. has important implications for the use and trade of various types of crude oil. These implications were potentially exacerbated by the U.S. export ban on crude oil, a policy which was in effect until the end of 2015.

In assessing the implications of the U.S. light oil boom, we make two contributions to the literature. First, we introduce two sources of heterogeneity into a general equilibrium model with endogenous oil prices: we consider three different types of oil that are imperfect substitutes into the refining process, and we assume differences between refineries in the U.S. and the rest of the world (ROW). Second, we assemble a comprehensive data set that contains information on crude oil quality in order to build our model on solid microeconomic foundations. One key point to highlight is the importance of examining detailed oil data and introducing heterogeneity in crude oil types and refining technology. If we were to only use aggregate data and pool different types of crude oil into one single oil sector, we would not be able to assess the implications of the shale oil boom for trade in different types of oil, relative prices of oil, and specialization. In addition, examining the distortionary effects of the crude oil export ban would not be possible.

Key changes in the data from 2010 to 2015

We gather data on production and prices of different types of crude oil as well as trade flows and refiner use of different types of oil. We define three categories of crude oil using API gravity as our metric. Our time period is 2010-2015, from the year the boom started, to the removal of the ban. We document that from 2010 to 2015 U.S. light oil production more than tripled, while production increases outside the U.S. were from medium and heavy crudes. In addition, U.S. refiners' use of light oil increased substantially, while medium crude use declined and heavy crude use increased from 2010 to 2015. Refined products production and exports increased considerably, as the export ban did not apply to refined petroleum products. We document dramatic shifts in the quantity and types of oil being imported as well: U.S. light oil imports dropped sharply, medium oil imports declined and heavy oil imports increased with the shale boom. These facts help justify the features of our model.

Methodology

The world economy is represented by a dynamic stochastic general equilibrium model that consists of two countries, the U.S. and the rest of the world (ROW), building on Backus and Crucini (2000) and Bodenstein et al. (2011). The key differences are that we introduce heterogeneous oil, endogenous oil production and refining. Our model also features an occasionally binding export ban on U.S. crude oil. Both countries produce crude oil, refined products (fuel), and a non-oil good. Their preferences and technologies have the same functional forms. Crude oil is produced using the non-oil good as an input and is used only to produce fuel. Production of refined products requires capital, labor, and a composite of the three types of crude oil with different elasticities of substitution across inputs. The non-oil good is produced using capital, labor, and refined products. Households consume a composite of fuel and the non-oil good. The model also features an internationally traded bond to allow for trade imbalances.

We solve the model numerically, which requires us to calibrate the model. We obtain micro estimates of three key model parameters using simulated method of moments: the elasticities of substitution across different oil types and the elasticity of substitution between oil and other factors of production. We carefully calibrate the remaining model parameters targeting a set of first and second order moments for oil-related and macro variables.

Our goal is to investigate the effects of the U.S. shale oil boom on the U.S. economy, trade, and the global oil market. We model the shale oil boom as a series of exogenous technology shocks that lower the cost of producing light oil in the U.S. Given that the export ban was in place, our baseline model incorporates the ban. We also consider the U.S. shale boom in an alternative model that ignores the ban, i.e. a free trade model.

Results

We find that the shale boom had significant effects on the U.S. economy, trade flows and the global oil market. In addition, the export ban was a binding constraint, particularly in 2014 and 2015, and likely would have remained a binding constraint thereafter, had the policy not been removed at the end of 2015.

Our model can match several important aspects of U.S. oil market data during the boom. We find that the increase in light oil supply causes light oil prices and fuel prices to fall. U.S. refiners increase their use of light oil but much of the new production simply crowds out imports of light oil, as in the data. The decline in imports generates a major improvement in the U.S. oil trade balance, by more than one percentage point (as a share of GDP), in line with the data. The decline in light crude oil imports is large enough to make the export ban a binding constraint for several years. Properly modeling and calibrating the refinery sectors is key to this result, as it is driven by the fact that the U.S. refinery sector is specialized in processing heavy crude relative to the rest of the world.

The export ban distorts light crude oil prices in the U.S. relative to the rest of the world and relative to other types of crude oil, providing a cost-advantage to U.S. refiners who over-process light crude oil and take market share from refiners elsewhere. We also show that had there been no ban during the shale boom from 2010 to 2015, domestic light oil prices would have been higher and the U.S. would have become a net exporter of light crude oil consistent with the recent data.

During the boom, cheaper fuel prices boost household consumption and firm fuel use and increase both non-oil output and aggregate consumption, implying positive spillovers to the aggregate economy. We find that the shale oil boom boosted U.S. real GDP by 1 percent from 2010 to 2015 which accounts for about one tenth of actual GDP growth over this period. This suggests that the boom has contributed to the recovery from the Great Recession.

References

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Pre-conference Seminar-Equilibrium Methods for Analysis of Environmental Policy in the Power Sector

SUMMARIZED BY AMOS OPPONG, DOCTORAL RESEARCHER, UNIVERSITY OF ELECTRONIC SCIENCE AND TECHNOLOGY OF CHINA

On May 28th, a day prior to the commencement of the IAEE International Conference, 28 participants including three experts and twenty-five young professionals from diverse academic backgrounds and various institutions around the globe met at HEC Montreal for a seminar on exploring a plethora of equilibrium methods used in analyzing environmental policy in the power sector.

Associate Professor *Yihsu Cheng* of Baskin School of Engineering at the University of California, Santa Cruz, USA; Professor *Makoto Tanaka* of the National Graduate Institute for Policy Studies, Japan; and Professor *Afzal S. Siddiqui* of University College London [UK], Stockholm University [Sweden], and HEC Montreal [Canada]; collaborated well with each other and successfully steered the contents of key topics discussed in the seminar to address concerns in the power sector that hitherto troubled participants.

The three experts combined interactive tools including in-depth introduction, robust mathematical modeling, and real-world case studies to delve deeper into the numerous topics discussed at the seminar. Topics discussed include environmental externalities, policies and features of power sectors; equilibrium solutions in cases of mixed complementarity problems, environmental policies in Nash-Cournot as well as Stackelberg leader-follower frameworks, and decentralized approach versus central planning for sustainable transmission expansion in power markets. Participants interacted well with one another, networked among themselves and asked a myriad of questions to the experts and peers during the seminar and at the student gathering at Café-Bar Le Saint-Sulpice [on May 29].

The organizers extend their gratitude to the Professors and participants for making the seminar a success.