Quantitative effects of the shale oil revolution ☆

Cristiana Belu Mănescu [a], Galo Nuño [b,*]

[a] European Commission, Directorate-General Economic and Financial Affairs, Rue de la Loi 170, 1040 Brussels, Belgium
[b] Banco de España, Alcalá 48, 28014 Madrid, Spain

HIGHLIGHTS

- We analyze the impact of the "shale oil revolution" on oil prices and economic growth.
- We employ a general equilibrium model of the oil market in which Saudi Arabia is the dominant firm.
- We find that most of the shale oil revolution is already priced in.
- We also analyze the decline in oil prices in the second half of 2014.
- We find that unanticipated supply shocks played the major role in the fall.

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ABSTRACT

The aim of this paper is to analyze the impact of the so-called "shale oil revolution" on oil prices and economic growth. We employ a general equilibrium model of the world oil market in which Saudi Arabia is the dominant firm, with the rest of the producers as a competitive fringe. Our results suggest that most of the expected increase in US oil supply due to the shale oil revolution has already been incorporated into prices and that it will produce an additional increase of 0.2% in the GDP of oil importers in the period 2010–2018. We also employ the model to analyze the collapse in oil prices in the second half of 2014 and conclude that it was mainly due to positive unanticipated supply shocks.

1. Introduction

Oil markets have recently undergone a significant transformation with the unexpectedly strong rise in the US production of shale oil. Shale oil refers to conventional oil (light oil with low sulphur content) trapped in very low-permeability tight formations known as shales, which makes extraction difficult. The combination of horizontal drilling techniques together with hydraulic fracturing, developed in the 1970s, and rising oil prices have made the exploration and exploitation of large volumes of shale oil possible. Shale oil is only one subset of a broader category of unconventional oil – known as "tight oil" – which is conventional oil trapped in very low-permeability formations and extracted by the unconventional methods mentioned above. However, the convention in the press is to use the terms "shale oil" and "tight oil" interchangeably when referring to oil extracted from all low-permeability formations (i.e. not only oil from shale formations). We follow this convention throughout the paper and refer to the entire tight oil category as "shale oil".[1]

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[1] Unless otherwise stated, by shale oil we refer to what the Energy Information Administration (EIA) calls "tight oil" and the International Energy Agency (IEA) calls "light, tight oil". The term tight oil does not have a specific technical, scientific, or geologic definition. Tight oil is an industry convention that generally refers to oil produced from very low-permeability shale, sandstone, and carbonate formations. Some of these geologic formations have been producing low volumes of oil for many decades in limited portions of the formation.

In the Unites States, the extraction of shale oil has grown dramatically over the last few years taking the market by surprise. In 2013, the Unites States is estimated to have produced 3.5 mb/d of shale oil which is three times higher than the amount it produced in 2010 (Energy Information Administration-EIA, 2014). By 2020, US shale oil is estimated to reach 4.8 mb/d, representing about a third of total US supply. This is having profound implications for the US economy, in terms of higher US energy independence and a decline in its trade deficit. More generally, from a global perspective, this has been a major factor supporting non-OPEC supply growth and contributing to the relative stability of Brent oil prices until mid-2014. Moreover, although the Unites States is expected to remain the dominant shale oil producer for the next decade, technically recoverable shale oil resources are estimated to be abundant also outside the Unites States (five times the size of US shale oil resources according to EIA, 2013).

In response, a rich body of academic and non-academic literature by investment banks, energy companies, national and international organizations and energy pundits has emerged in an attempt to assess the magnitude and implications of the shale oil revolution. Most studies concentrate on the difficult task of estimating the size of shale oil production and resources (e.g. Energy Information Administration, 2014; International Energy Agency, 2013 and earlier studies) or analyze the factors which caused the shale oil revolution to occur in the Unites States and not elsewhere (e.g. Alquist and Guenétte, 2014; Maugeri, 2012). Several studies use global econometric models to estimate wider economic implications of the shale oil revolution (e.g. PWC, 2013), whereas a few focus on the impact on oil prices, usually gauged by relatively simple methods (e.g. Sharenow and Worah, 2013). We complement these works by using a state-of-the-art general equilibrium model to assess the impact of shale oil on oil prices and GDP. We employ the model of Nakov and Nuño (2014) in which the oil market is characterized by the presence of a dominant supplier with a competitive fringe and which has been shown to replicate fairly well the dynamics in the oil market.[2] The key advantage of our model is that the reaction of Saudi Arabia is embedded in the model. Saudi Arabia is the largest OPEC producer and also has the largest spare capacity which gives it substantial power among OPEC members to influence markets. As a result, the price impact of shale oil will necessarily depend on the response of Saudi Arabia. In contrast to similar existing studies which typically make an explicit assumption about Saudi Arabia (PWC, 2013), in our framework the response of Saudi Arabia is endogenously determined.

We assess the impact of the shale oil revolution under three scenarios for US shale oil projections until 2018: a baseline scenario using the Energy Information Administration (2014) projections of US shale oil and two alternative scenarios to capture the uncertainty surrounding the baseline projection. In all three cases we assume that Saudi Arabia maximizes its discounted flow of profits. Our results suggest that (i) most of the shale oil revolution has already been incorporated into oil prices and (ii) even considerable *anticipated* changes in the scale of the production will have only a small effect on prices. The oil price impact of the increase in shale supply under the different scenarios amounts to changes of less than ± $4 per barrel (pb). The relatively muted impact on prices onwards stems mainly from the anticipated nature of the shock and from the contraction in non-shale world oil supply, largely from Saudi Arabia, which helps to moderate the change in world oil production and sustain prices. According to the

model, in response to lower oil prices and a reduced oil market share, Saudi Arabia curbs its investment in new production capacity which leads to a deterioration in its spare capacity position. Finally, the model suggests that the shale oil revolution will produce an increase of 0.2% in the GDP of oil importers by 2018, compared to 2010.

If most of the shale oil revolution is already priced-in and therefore its impact on current price dynamics is negligible, how can we explain the collapse in oil prices in 2014? We discuss three complementary explanations: (i) the increase in non-US supply that happened in the second half of 2014; (ii) the global economic slowdown, which depressed most commodity prices; and (iii) the deviation of Saudi Arabia from its optimal rule as it decided not to reduce its production in order to accommodate the increase in supply by other producers. These three factors were unanticipated in contrast to the anticipated nature of the shale oil revolution, at least since 2010–2011. We take the model to the data on oil prices and quantities in order to quantify the relative impact of these three factors. We conclude that supply factors played the largest role.

The analysis of the 2014 collapse in oil prices complements the existing literature analyzing this episode, based on structural VARs. Badel and McGillicuddy (2015) and Baumeister and Kilian (2015) conclude that demand shocks played the major role. In contrast, Baffes et al. (2015) find that supply shocks accounted for roughly twice as much as demand shocks in explaining the drop in oil prices during the recent episode.

This paper relates to the literature on general equilibrium models that explicitly analyze the oil market. Recent examples include Backus and Crucini (2000), Blanchard and Gali (2010), Bodenstein et al. (2011, 2012), Bodenstein and Guerrieri (2011), DeMiguel and Manzano (2006), Leduc and Sill (2007), and Nakov and Pescatori (2010a,b).

The structure of the paper is as follows. Section 2 describes the magnitude and importance of the shale oil revolution. Section 3 introduces the model and the shale oil production scenarios and discusses the main results. Section 4 analyzes the 2014 episode. Section 5 discusses the policy implications. Finally, Section 6 concludes.

2. The transformational impact of US shale oil for the oil market

2.1. The size of the US shale oil revolution

In the United States, the production of shale oil has grown dramatically over the last few years. In 2013, the Unites States is estimated to have produced 3.5 mb/d of shale oil, which is three times the as much as in 2010 (Energy Information Administration, 2014). This accounted for nearly half of US crude oil supply and almost a third of its total oil supply in 2013 (see Fig. 1). As a result, shale oil put an end to a prolonged period of declining supplies: for the first time, the Unites States produced more oil in 2013 than in 1985. Looking ahead, US shale oil production is expected to continue to rise and peak at 4.8 mb/d in 2020 according to the EIA (see Table 1), before gradually declining to 3.2 mb/d by 2040.

From a global perspective, the rapid rise of US shale oil has been the main driver behind the increase in non-OPEC supply (see Fig. 2). During 2009–2012, US oil supply grew, on average, at a sustained annual rate of 6.7%, while non-OPEC oil supply produced outside of the Unites States was stable, on average.[3] The US share

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[2] A large portion of the literature suggests that the 'dominant supplier with competitive fringe' view of the oil industry is the one that best describes the empirical evidence. Examples include Mabro (1975), Dahl and Yucel (1991), Adelman (1995), Alhajji and Huettner (2000a,b), and Brémond et al. (2011).

[3] At the time of writing, the latest EIA data for shale oil are for 2012, while data for 2013 onwards are projected. See Energy Information Administration (2014).