

The Price Elasticity of Shale Supply: Financing Constraints and Resource Endowment

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1. Overview

Production of natural gas from shale formations had a big impact on natural gas and LNG trade in the U.S. and outside. A recent report by the Energy Information Administration (EIA, 2018) suggests that the shale gas production growth will continue increasing, despite a very gradual natural gas price increase expected under “Reference scenario”. That growth is expected to be supported by the shale resource productivity improvements as the commercially attractive areas are limited and quickly exhausted (EIA, 2015, Ikonnikova et al., 2015; Gulen et al., 2013). Smith and Lee (2017) offer a framework to incorporate resource base heterogeneity and productivity into the analysis of the price elasticity of supply expanding on the common supply curve analysis. Shale resource development dynamics, however, suggests that other factors must be taken into account as well, namely the ability to produce firms to raise external funds needed to support production growth. Many shale gas producing firms have limited internal funds available for reinvestment and rely on asset-based and cash-flow-based lending (Denning, 2017; Azar, 2017). External funds affect the budget or investment constraint and hence, play an important role determining supply.

The goal of the present work is twofold. First, we explore how and why the price elasticity of shale gas supply may depend on a producer's a) resource endowment and b) financing decisions, and how those two determine investments and supply responsiveness to price. To that end, we build a simplified analytical model capturing producer's investment and investment financing behavior. Second, we are looking for empirical evidence to support our theoretical conclusions and developed intuition. To test our model we use data from the Barnett shale play for the period between 2006 and 2016, when increasing and then decreasing natural gas prices were observed. We use available data, on resource-in-place, production, individual well costs, and energy prices to formulate hypothesis consistent with our theoretical investigation.

The present study contributes to the two major streams of research: 1) empirical studies of elasticity of supply and 2) works investigating the relationship between financing constraints, firm's growth, and industry dynamics. The studies on elasticity are commonly focused on econometrical analysis focusing on market power distribution and supply curve assumptions (e.g. Adesoji, A., 1991; Ponce&Neumann, 2014), with a few exceptions (e.g. Heal, 1976; Smith&Lee, 2017) taking a closer look at the role of productivity improvements and resource exhaustion. In contrast, studies on financing, often lack empirical data for analysis and investigate the channels of financing and their role for firm's growth without taking a close look at effects the financing constraint have on supply (Fazzari, et al., 1988; Xian, 2016). We believe our research pioneers in connecting the elasticity of supply to firm's financing and growth model and testing the result on real-world data.

2. Theoretical Analysis

In the first part of this section, we develop a model describing investing behavior of a resource producing firm. The model aims at representing firm's decisions taking into account trade-offs associated with investment financing. After determining the set of variables and parameters in the supply function $Q(\cdot)$, we derive the price elasticity of supply $\varepsilon(Q(\cdot), p)$ in the second part of this section. The section concludes with the hypothesis, which we test in the next section, on how the price elasticity of supply depends on the firm's financial situation, resource endowment, and the expected resource prices.

We consider a firm with a natural resource endowment, represented by a collection of N potential projects. Each period t a set of projects N_t get executed, $N_{t+1} = N_t/N_t$, with the value of N_t representing “assets at hand” and converted into cash and left for future development N_{t+1} being “growth assets”. Furthermore, projects are grouped, based on their location, developed, with low risk, and undeveloped, with high risk from a lender perspective. The firm has information to assign all projects low risk, but different expected production q^i . To reduce the lender's perceived risk, the firm has to execute a project near the undeveloped location.

Each period t the firm makes a decision on which projects $N_t: \{q^i\}_{i \in N_t}$ and from which blocks, developed or undeveloped, to execute. The decision defines the total supply $Q_t = \sum_i q^i$ and is assumed to maximize the total value of the firm or its assets. The choice of a project also depends on the availability of the investment capital. The firm may use its own funds, reinvesting the cash flows obtained at the end of the previous period, and if insufficient, acquire external funds, D_t , which lenders offer at some costs $r = r^f + r^\sigma(\sigma) + r^s(s)$, including the market risk-free rate r^f , the lender's view on the project risk $\sigma^2 = \text{Var}(q)$ and the requested risk premium $\frac{dr^\sigma}{d\sigma} \geq 0$, and finally, on the risk associated with the firm size or debt coverage $r^s(s) = s \cdot D_t / CF_t$. This asymmetry in projects' evaluation, stemming from the specificity of the resource development technology and need of specific expertise, leads to the fact that external funds are not perfect substitutes to internal funds with the latter having a cost advantage in financing.¹ Under these circumstances, firms' investment and financing decisions, on how much to borrow and for which projects, are interdependent.

The difference in capital costs translates into the evaluation of the projects: projects funded through external capital in undeveloped blocks are less attractive, than those in developed blocks even if the expected productivity is the same. The lower cost of capital for any q^i lead to higher assigned profitability. The firm is set to maximize its total value W subject to its budget constraint.

Trade-offs The setup of the producer's maximization problem reveals the following trade-offs. First, the firm may not be able to realize all the profitable projects because of the lack of own funds and increasing costs of external capital. Second, the firm has incentives to use own cheaper funds to develop new blocks to signal the lenders of their true productivity and reduce the cost of capital for the development of those blocks in the future and therewith increase the assigned value to that part of its growth assets. Finally, due to the differences in capital costs, the firm may execute projects which do not look attractive to the external lenders but present some positive value to the firm and hence, increase its operational profit boosting the total value W and the capital available for reinvestment in the next period.

Solution To solve the firm's maximization problem, we employ the probabilistic solution developed for mathematically similar knapsack problems.

4. Results

Our preliminary results suggest that elasticity of supply was and will change over time until producing firms rely solely on internal funding or do not meet the cost of financing asymmetry. Also, we estimate that as firms mature, decreasing the share of external funding, they become less "reactive" to price drops. However, the elasticity may change also with the availability of "good" vs. "bad" locations and hence, both short-term and long-term elasticity's change over time.

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¹ For other justifications against perfect capital market assumption, see Fazzari, et al., 1988; Fazzari, et al., 1991.