Introduction	wouvation	Model	Results
	The Beginning of the E	End of the Age of O	il
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Introduction

- Drilling Prospect Heterogeneity
 - Beginning of end is feasible
 - Oil in the ground
- Agenda
 - Motivation
 - Model Setup
 - Results

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Research Goal

Theoretical model of oil/gas production with:

- Drilling prospect heterogeneity
- Geological characteristics

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Drilling Prospect Heterogeneity



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Drilling Prospect Heterogeneity





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Geological Characteristics



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Geological Characteristics

Production and Capacity



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State and Control Variables

- Two state variables
 - Drilling prospects, A(t)
 - Defined by geological factors, not physical oil in place
 - Capacity to produce oil, K(t)
 - Both exhaustible
- Two control variables
 - A(t) converted to K(t) through drilling, q(t)
 - Oil produced at rate z(t)
 - Constant decline rate, α

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Drilling Costs

- Drilling costs are
 - increasing and convex in the drilling rate, q(t)
 - decreasing and convex in the drilling prospect stock

C(q(t), A(t)) $C_q(q(t), A(t)) > 0$ and $C_{qq}(q(t), A(t)) \ge 0$ $C_A(q(t), A(t)) < 0$ and $C_{AA}(q(t), A(t)) \ge 0$

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Heterogeneous Drilling Prospects



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Model

 $\dot{A}(t) = -q(t)$



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	Model	
	$\dot{K}(t) = c$	$q(t) - \alpha z(t)$
q(t) t 102 103 104 105		

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 $\dot{A}(t) = -q(t)$

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 $\dot{K}(t) = q(t) - \alpha z(t)$



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 $\dot{A}(t) = -q(t)$

$$\dot{K}(t) = q(t) - \alpha z(t)$$



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Utility and Scrap Value

- Consumers derive increasing and concave utility from production, U(z(t))
- A scrap-value is collected at the beginning of the end, S(K(T))
 - Discounted stream of future utility

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Shadow Values

- $\lambda^{A}(t)$ = marginal value of a drilling prospect at t
- $\lambda^{K}(t)$ = marginal value of capacity at t
- r = discount rate

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Evolution of Drilling Prospect Shadow Value



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Capacity Value vs. Prospect Value

 $\lambda^{\mathcal{K}}(t) - \lambda^{\mathcal{A}}(t) = C_q(q(t), \mathcal{A}(t)) \quad \text{if} \quad q(t) > 0$



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Optimal Beginning of End

Three conditions for optimal beginning of end:

$$- \lambda^{A}(T) = 0$$

$$- \lambda^{K}(T) = S'(K(T))$$

$$- C_q(q(T), A(T)) = C(q(T), A(T))/q(T)$$

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Concluding Remarks

- Model of oil production with geological characteristics and heterogeneous drilling prospects
- Reasonable to expect beginning of end w/ oil in the ground
- Next steps:
 - Policy analysis
 - Simulations
 - Uncertainty

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