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ECONOMIC EFFECTS OF OPENING
ARCTIC NATIONAL WILDLIFE REFUGE
TO OIL DRILLING

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WHITMAN
COLLEGE

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Overview:

Nearly 40 percent of the United States' primary energy comes from petroleum, forcing the world's largest economy to be heavily dependent on foreign oil. In 2009, the U.S. consumed nearly 19 million barrels of oil per day at a price around \$75 per barrel, according to the U.S. Energy Information Administration (EIA)¹. Due to its heavy dependence on imported oil, the U.S. continues to be held hostage to price fluctuations in the oil market. Over the past decade, oil prices swung between \$35 per barrel and \$149 per barrel, a reality that quickly changed Americans' perception of oil dependency. Although the U.S. economy could reduce its reliance on oil by reducing consumption through the incorporation of various alternative energy sources, the likelihood of Americans embracing conservation is slim. Hence, arguments for opening additional U.S. land and offshore waters to oil drilling have gained more attention. This is specifically the argument for proposals to develop Alaska's Arctic National Wildlife Refuge (ANWR) oil reserves². This paper will focus on the environmental and economic implications of opening ANWR to oil development.

While the United States faces challenges in its quest for alternative energies, environmental regulations continue to limit possible drilling sites, including ANWR³. ANWR, the largest national wildlife refuge in the United States, was established in 1980 through the Alaska National Interest Lands Conservation Act. The act's main goal was to conserve the region's fish and wildlife populations and habitats in their natural diversity with special emphasis on the Porcupine Caribou, bears, wolves, and other migratory birds. To accomplish this, ANWR was set aside for precaution of its unique habitat space, a wildlife sanctuary of tundra and marshes. However, development proponents view this coastal plain as one of the most promising

¹ "Alaska Oil Profile." *U.S. Energy Information Administration - EIA - Independent Statistics and Analysis*. 29 Nov 2010. Web. 06 Dec. 2010. <http://www.eia.gov/state/state_energy_profiles.cfm?sid=AK>

² Snyder, Brian. "How to Reach a Compromise on Drilling in ANWR." *Energy Policy* 36.3 (2008): 937-39. Print

³ *Ibid*, 937.

U.S. onshore oil and gas prospects. The proposed oil development would threaten the future of this wilderness retreat⁴.

Among the many areas with oil deposits within ANWR, an area referred to as “1002” potentially contains enormous oil reserves. The federal government, the state of Alaska, and the Native American Corporation jointly own this area, which raises concerns over property rights relating to the pristine acreage⁵. According to the U.S. Geological Survey⁶, ANWR has an estimated 10 billion barrels of recoverable oil under 1.5 million acres. This amount of oil recovered would likely reduce the U.S. dependence on imported oil.

Although the current U.S. policy stance is to sustain prohibition of development to protect the area’s biological, recreation, and subsistence values, the debate over potential oil drilling in the region continues. There seem to be two primary positions in the debate. One is that Congress could pass legislation permitting oil and gas leasing in the 1002 area. With this option, Congress could decide the pace and conditions for any oil or gas development. Alternatively, protectionists argue that no action would prevent onshore energy development and the oil deposits could be saved for an unspecified “right time”⁷.

An introduction to the potential environmental implications of opening ANWR to oil drilling will be examined. Next, the total economic value of opening ANWR (TEV_o) and the total economic value of keeping ANWR closed (TEV_c) will be compared. The value of oil to be recovered if ANWR were opened depends upon the price of oil. This will require an analysis

⁴ Billingham, Sarah I. “Arctic National Wildlife Refuge: Issues and Legislation.” *Congressional Research Service*. New York: Nova Science Publishers, Inc., 2009. Print.

⁵ Gelb, Bernard A. “ANWR Development: Economic Impacts.” *Congressional Research Service*. New York: Nova Science Publishers, Inc., 2006. Print.

⁶ “Arctic National Wildlife Refuge, 1002 Area, Petroleum Assessment, 1998, Including Economic Analysis.” *U.S. Geological Survey*. 2001.

⁷ Lieland, Barbara T. “Arctic National Wildlife Refuge: Review, Controversies, and Legislation.” *Congressional Research Service*. New York: Nova Science, 2006. Print.

using the N-period model of non-renewable resource extraction and the effect of a new deposit of the non-renewable resource (ANWR oil) into the market.

Part I: Environmental Implications for Opening ANWR

Opening ANWR to oil drilling would cause environmental damage in both preparation and production locations. The construction of an oil drill platform used to pump oil from the ground significantly transforms the surrounding area. The surrounding land and water areas are vulnerable to habitat destruction and contamination of oil drilling's hazardous waste materials. In the case of ANWR, the potential oil reserves are located in pristine and isolated locations, requiring road construction, leveling of the drilling area, and setup of water reserves and waste disposals⁸. Road construction requires large amounts of gravel that are either hauled in from outside sources or from the destruction of natural cliffs and boulders. Next, the land, located near the oil deposit and water source, is leveled by clearing forests and filling in wetlands areas. A substantial water reserve is an important element to drilling. This preliminary construction for oil drilling is devastating to the surrounding terrain and endangers the survival of aquatic life.

The predicted final stage of drilling involves considerable surface disturbance, including construction of drilling sites, campsites, and airstrips. The continued land transport of equipment and personnel to drilling sites further wears on the roads, contributing to the removal and compaction of tundra, which can cause thawing of permafrost. The combination of thermal erosion and hydraulic erosion over time creates slumping and ravines. In most cases, the waste pits are dug and lined with plastic to protect waste from leaking into the environment. Due to ANWR's sensitive location, the waste will most likely be hauled offsite, which reduces the risk

⁸ Jenkins, Page. "The Impact of Oil Development on the North Slope." *Natural Resources Defense Council*. 2001.

of waste material leakage. Overall, the construction of a drill pad negatively impacts the surrounding habitat⁹.

The construction of the oil developments can negatively affect the surrounding environment and wildlife. Roads and pipelines divide populations, disrupt migratory patterns, and alter the predator and prey balance. Should ANWR be opened to oil drilling, the 1002 area will most likely be targeted for oil development due to its high estimations for oil reserves, its accessibility to water sources, and transportation routes¹⁰.

The 1002 area is home to Alaska's fragile ecosystem, and oil development in this region would dramatically, and potentially permanently, jeopardize the wildlife and surrounding regions. The 1002 area is known as one of the most productive regions for wildlife and the center of wildlife activity within ANWR; thus alterations to this region can cause devastating effects. This region has a relatively short summer season, where many species mate. Caribou, polar bears, musk oxen, and over 135 migratory birds come and gather during the summer. This breeding period is vital to the survival of the species¹¹. Oil developments would disrupt migration patterns, and possibly lead to declines in animal populations.

In the case of the Porcupine Caribou herd, the herd spends the winters south of the Brooks Range in Alaska and Canada. Then in the summers, the herd migrates to the 1002 area to breed and give birth to their calves. Should the caribou migration be slowed by late thaws or heavy snows, the herd might not make it to the 1002 area before calving. This creates a serious problem due to the presence of predators in the surrounding Brooks Range. The Brooks Range is home to more predators (such as bears, wolves, and golden eagles) than the more sheltered area

⁹ "Impacts of Construction and Equipment on Energy Industries." *U.S. Energy Information Administration - EIA - Independent Statistics and Analysis*. 2007. 06 Nov. 2010. < <http://www.eia.doe.gov/oiaf/aeo/otheranalysis/cecei.html>>.

¹⁰ Bird, Kenneth J., and David W. Houseknecht. "Arctic National Wildlife Refuge, 1002 Area, Petroleum Assessment, 1998, Including Economic Analysis." *United States Geological Survey* (2001). Print.

¹¹ Jenkins, 2.

of ANWR. In 2000, heavy snowfall delayed the caribou migration, resulting in the lowest recorded calf survival recorded. This situation demonstrates the importance of the 1002 area use by the caribou¹².

Specifically, road construction would be particularly detrimental in the 1002 area. Studies show that the density of caribou and other animals' population decreases near roads and developed areas. This dispersion of population leads to the decrease in chances of finding a mate, which could ultimately push animals to breed in undesirable areas, resulting in a decrease in the number of offspring¹³.

Environmental Effects of Arctic Oil Development, Prudhoe Bay:

The potential environmental effects of opening ANWR to oil development will likely be similar to the current environmental effects of such development in surrounding area of Prudhoe Bay, an oil development located about 60 miles away from ANWR. The Prudhoe Bay oil development was constructed in 1967 and over the past 25 years has produced approximately 15 billion barrels, resulting in billions of dollars in profit¹⁴. However, these benefits come with costs.

The Prudhoe region has been transformed by the development of oil drilling. Over 400 square miles of formerly pristine landscape have been permanently altered by the more than 1,500 miles of roads and pipelines which were laid during construction of the site. The U.S. Fish and Wildlife Service¹⁵ reported this habitat destruction and pipeline and road disruption led to more than 15,000 bird deaths, and the intake of saltwater for drilling removed over 400,000 fish larvae. According to the Congressional Office of Technology Assessment, the bear and wolf

¹² Lieland, 16.

¹³ Lieland, 16.

¹⁴ Lieland, 78.

¹⁵ "Arctic National Wildlife Refuge, 1002 Area, Petroleum Assessment, 1998, Including Economic Analysis." *U.S. Geological Survey*. 2001.

populations significantly declined in the Prudhoe Bay area, and caribou densities decreased within a 4km zone of pipelines and roads. The arctic ecosystem remains a fragile balance of interdependent prey and predator relation, and any fluctuation in the animal populations, including fewer offspring or breeding in a different location, has dramatic short-term and long-term effects¹⁶.

Oil development not only destroys the surrounding habitat, but also releases waste materials that can cause permanent damage. Millions of gallons of waste from oil and gas operations would enter into open pits or would be injected into subsurface cavities, frozen into permafrost, and discharged directly into the air and water¹⁷. Each year, Prudhoe releases over 43,000 tons of nitrogen oxides, which is more than twice the amount emitted by Washington, D.C. Oil leaks between tankers and pipelines are inevitable and pollute the areas surrounding Prudhoe Bay. In 1995, approximately 500 spills were reported involving more than 80,000 gallons of oil diesel fuel, acid, biocide, ethylene glycol, drilling fluid, produced water, and other materials; this averages to one spill every 18 hours¹⁸. In addition to these reportable spills of oil products and hazardous materials daily, noise, and air pollution are potentially damaging¹⁹.

In the case of ANWR, more specifically the 1002 area, Congress could authorize oil development and impose higher standards of environmental protection. The effectiveness of regulation would be affected by the choice of administering agency and the degree of agency discretion. For ANWR, provisions could include best available technology or best commercially available technology to reduce the dramatic environmental and ecological effects experienced by the Prudhoe Bay oil development.

¹⁶ Lieland, 62.

¹⁷ Billingham, 16.

¹⁸ Lieland, 60.

¹⁹ Lieland, 60.

Part II: Total Economic Values of ANWR Oil Development

An economic assessment of the desirability of opening ANWR could be undertaken by comparing the TEV (TEV=Use Value + Non-use Values + Option Values) of opening ANWR to the TEV of keeping ANWR closed to oil development. The use value is the present value stream of the current and expected future goods and services flows provided by an environmental asset. If ANWR were opened, this use value would include the current and future profits associated with the sale of the oil to producers and the value to consumers of the production of goods and services provided by the use of the oil products, including energy. The option value of the environmental asset is the amount society is willing to pay to maintain the option of potential speculative future goods and services flows that may be provided by the environmental asset. This involves the additional value associated with maintaining the oil reserves for a later use of enjoyment. By not extracting the oil in the present future extraction is possible. Thus, when the price of oil increases, its profit of sale increases²⁰.

On the other hand, there are non-use values associated with maintaining closure to oil development would be lost if ANWR were opened. Non-use value is the value of the goods and services produced by the environmental asset that is independent of current, future, and speculative value. This can include the existence value: the value people are willing to pay to maintain existence of goods and services independent of current uses, as well as the intrinsic value, the sympathy motive, and the bequest value²¹.

Comparison of TEV of opening ANWR to TEV of closed ANWR is a form of cost-benefit analysis. Robert Hahn and Peter Passell²² offer a cost-benefit analysis that revealed positive net benefits from the development of oil production in ANWR. The benefits in the

²⁰ Tietenberg, Thomas H., and Lynne Lewis. *Environmental & Natural Resource Economics*. Boston: Pearson Addison Wesley, 2009. Print.

²¹ *Ibid*, 37.

²² Hahn, Robert, and Peter Passel. "The Economics of Allowing More Domestic Oil Drilling." *Energy Economics* (2008): 1-33. Print.

analysis included industry total revenue, total price-reduction benefit for the consumers of oil products, and reduced-disruption-cost/avoided expected costs of imported supply risk. Their costs included total direct costs to the industry, losses of total use value, associated with hunting and recreation, losses of non-use value, total greenhouse gas damages, total local air pollution damages, total traffic congestion costs, and total expected traffic accident costs. They compared the benefits and costs at two different prices of oil, \$50 per barrel and \$100 per barrel. The total net benefits were \$202 billion and \$591 billion for \$50 per barrel and \$100 per barrel produced from ANWR, respectively (Table 1).

Basic Concepts of Non-renewable Resources:

Oil is a non-renewable natural resource. There are unknown reserves and known reserves of oil, and this paper will focus on known reserves. Within the category of known reserves, there are three different types: current reserves, potential reserves, and other known reserves. Current reserves, like Prudhoe Bay, are known reserves that are profitable at current prices and current technology. Some ANWR reserves might be considered current reserves. Potential known reserves, like ANWR, are not currently profitable at present prices with existing technology, but could become profitable with an increase in the price of oil. Other known reserves are reserves that are known but only profitable if technology changes²³.

The U.S Geological Survey²⁴ reexamined ANWR 1002 area and prepared an updated oil resource assessment. In-place oil, as defined in the survey, is the amount of oil present, regardless of recoverability. Technically recoverable oil is the volume of oil included in the in-place volume of oil that may be recoverable using current recovery technology, regardless of

²³ Tietenberg, 167.

²⁴ "Arctic National Wildlife Refuge, 1002 Area, Petroleum Assessment, 1998, Including Economic Analysis." *U.S. Geological Survey*. 2001.

cost. Economically recoverable oil is the part of the technically recoverable oil for which the costs of discovery, development, and production are recoverable at a given price. From this assessment, the amounts of technically recoverable oil from the in-place oil resources for the entire 1002 area were estimated (Table 2). The deformed regions and undeformed regions are designated by their location within ANWR and the composition of stratigraphy. The undeformed regions are composed of crust that is more conducive to oil drilling and tend to have higher volumes of recoverable oil. Figure 1 demonstrates the relationship between these three distinctions in oil estimations. Going from in-place oil to technically recoverable oil to economically recoverable oil, the volume of oil decreases because the attainment of oil is taking into account the possibility of recovery and the profitability of extraction. Therefore the oil volume curves shift to the right (Figure 1).

Higher oil prices have drawn the attention of oil companies to previously inaccessible and unprofitable areas. The Energy Information Administration (EIA) reported that the operation of the pipeline is considered uneconomical if flows fall below 200,000bbl per day. EIA estimates that development beginning in 2008 would result in production beginning that same year with a peak in 2028, ranging from 510,000bbl per day to 1,450,000bbl per day²⁵, depending on the size of the resource. If estimates are correct, ANWR's production would represent 0.4%-1.2% of world's oil consumption and would reduce the world price of low-sulfur crude by \$0.41/barrel to \$1.44/barrel in 2026²⁶. Production at these levels would help to hold fuel imports steady at about 51% between 2018 and 2025, causing a corresponding reduction in crude oil imports relative to the scenario in which ANWR remains closed. In addition, oil production would help spread the costs of operating the Trans-Alaska Pipeline System.

²⁵ "Alaska Oil Profile," 1.

²⁶ "Alaska Oil Profile," 1.

Part III: N-period Model of Non-renewable Recourse of Oil:

Hahn and Passell's analysis highlights the importance of the price of oil for evaluating the net benefits of opening ANWR. Some important factors that affect oil prices can be explained using the N-period model of non-renewable resource extraction. We can consider the effect of opening ANWR to oil drilling and a new discovery of oil on the price of oil.

The basic theory of the optimal extraction of a non-renewable resource begins with the following simplifying assumptions: 1) the marginal extraction cost (MEC_t) function is constant with respect to time and quantity extracted, 2) the demand (D_t) function is stable and constant over time, 3) there is no uncertainty (a fixed known stock of resource), 4) there are no environmental externality problems, and 5) there are no market power problems. In this case MEC is the additional cost to extract an additional barrel of oil and accurately reflects the marginal cost society bears. In addition, MEC and marginal user cost (MUC), the discounted future marginal net benefit forgone by using a unit of the non-renewable source unit in the present, make up the total marginal cost to society (MC^s), ($MEC_0 + MUC_0 = MC^s$). The demand function accurately reflects the marginal benefits of society ($D = MB^s$). Under these conditions the following graphs can be constructed²⁷.

Price Path Function: The price path reflects the change in price of oil over time. At $t=0$, the initial price (P_0) includes the MEC_0 , which is constant, and the marginal user cost₀ (MUC_0). MUC increases exponentially over time by the discount rate $(1+r)^t$, ($MUC_t = MUC_0(1+r)^t$). Assuming P_t will always be greater than MEC_t throughout the oil extraction, oil will be extracted

²⁷ Tietenberg, 167.

to economic exhaustion. Economic exhaustion is when the P_{\max} is reached at the terminal time (T) and the quantity of the resource extracted at T is 0 (at T, $P=P_{\max}$ and $X=0$) (Figure 2a).

Extraction Path Function: The extraction path reflects the relationship between society's quantity demanded for estimated oil and the price. Starting at P_0 , the initial quantity of oil extracted can be determined by where P_0 intersects the demand function. As the price increases, shown in the price path graph, the quantity extracted will decrease (Figure 2b). This decrease in extraction of oil over time can be displayed on the extraction path function.

The sum of the extraction in all time totals the extraction path function and represents cumulative extraction. This area represents the entire stock at $t=0$. Since $MEC_t < P_t$, extraction of oil is always profitable, this leads to physical exhaustion (Figure 2c).

In this situation, physical and economic exhaustion are reached. This model shows that oil extraction will continue until resource depletion. Assuming the oil stock remains profitable, the industry has no incentive to stop production until there is no more oil to extract. A more complicated and realistic case of increased demand over time and increased MEC_t also yields increased P_t . This is important to show how increasing prices over time lead to increases in net benefits with ANWR open to oil development.

Opening ANWR to oil development will itself affect price and quantity extracted in a given period of time and over time change the P_t and extraction paths. The addition of oil from ANWR will increase the supply of oil and cause the price of oil to decrease. This decrease in price will cause the price path to shift down at the time of entry. At each entry of deposit at time (t' , t'' , t'''), the price function falls, but then increases at the rate of $(1+r)^t$. The addition of ANWR to the market would also increase extraction of oil and would extend the terminal period

(Figure 3). This is relevant if ANWR was not expected to be available until time t and then was suddenly opened.

Conclusion:

ANWR represents both an oil rich and wildlife rich environment. Due to ANWR's unique nature, it is difficult to find an effective balance between maintaining these two resources. Under the hypothetical model of oil development in ANWR, there would be dramatic habitat destruction and migration disruption, similar to the construction of Prudhoe Bay. However, with stricter regulations for ANWR development, the potential negative environmental implications would be reduced. Additionally, the benefit-cost analysis of Hahn and Passell revealed the benefits of opening ANWR to oil drilling outweighed the costs. Then assuming ANWR is opened for oil development, in the N -period model, there would be a shift downward in the price path and spike in the extraction path, resulting in an increase in oil extraction and a longer terminal time. In conclusion, ANWR oil development reflects benefits and costs, but without a thorough risk assessment of the oil development, it is difficult to compare them. Additionally, further research into other types of energy sources, and exploration into other oil deposits could help alleviate the need to tap into ANWR's oil reserves.

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<http://www.eia.gov/dnav/pet/pet_move_impcus_a2_nus_ep00_im0_mbbldpd_a.htm>.

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<http://www.eia.gov/dnav/pet/pet_a2_nus_ep00_im0_mbbldpd_a.htm>.

Table 1: *Benefit-Cost Calculations for ANWR (Billion\$)*

	\$50/barrel	\$100/barrel
	Total	Total
Benefits		
Revenue	345	714
Price-reduction benefit	30	61
Reduced-disruption-cost	31	32
Total Benefits	406	807
Costs of Drilling		
Direct costs	132	141
Use value	0	0
Non-use value	11	11
Greenhouse gas damage	0	0
Local air pollution	20	20
Traffic congestion	18	20
Traffic accidents	23	23
Total costs	203	217
Net benefits	202	591

(Hahn, 2010)

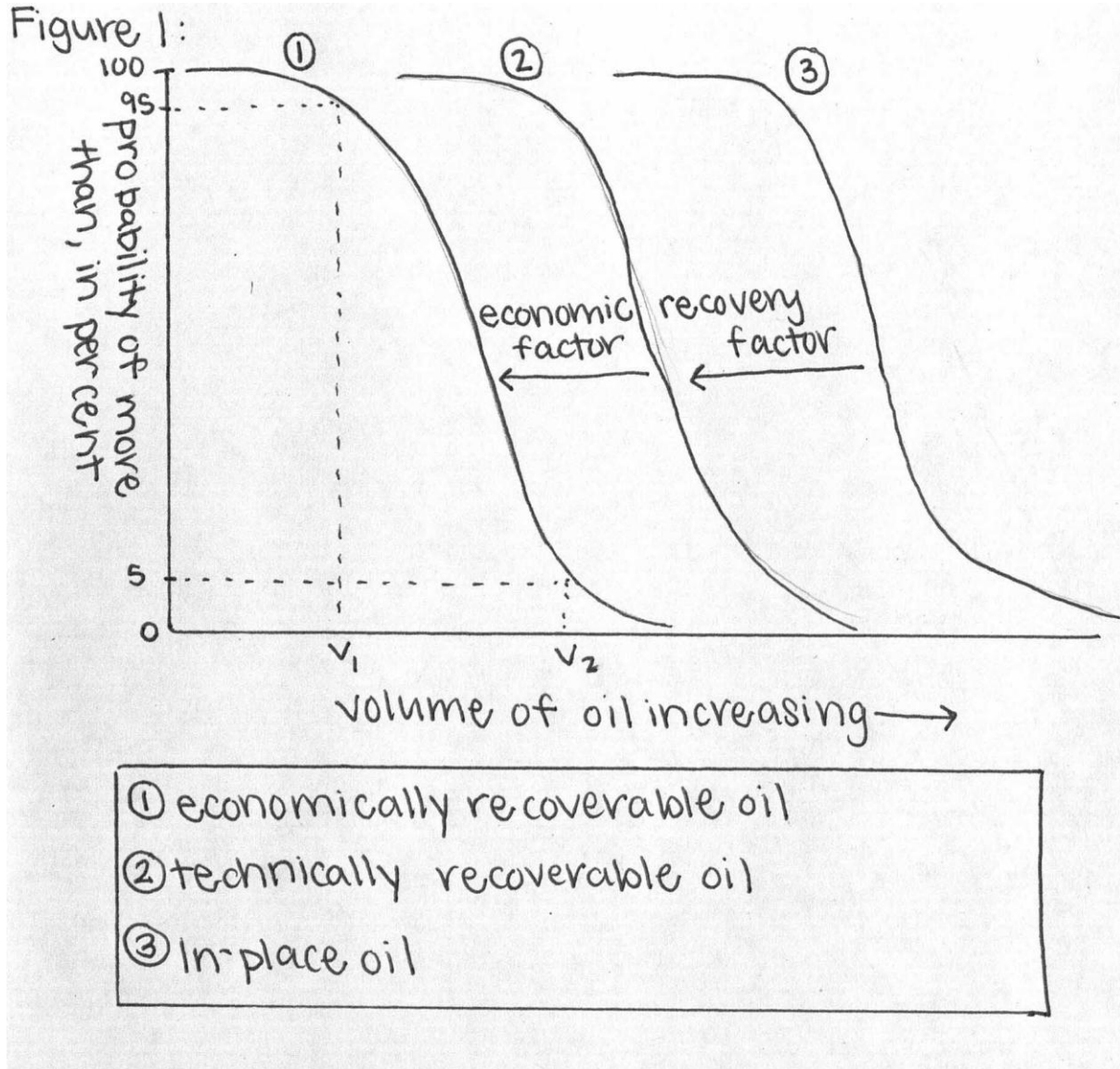
Table 2: *U.S. Geological Survey Estimations of Volumes of Technically Recoverable Oil in Various Regions of ANWR*

Area of Study	Volume of Oil, in million of barrels		
	P=95	Mean	P=05
Entire Assessment Area (1002 area, Native lands, and adjacent State waters)	5,724	10,360	15,955
ANWR 1002 area	4,254	7,668	11,799
Undeformed part of 1002 area	3,403	6,420	10,224
Deformed part of 1002 area	0	1,248	3,185

(“Arctic National Wildlife Refuge, 1002 Area, Petroleum Assessment, 1998, Including Economic Analysis,” 2001)

These estimations were presented with probabilistic uncertainty of 95-percent and 5-percent .

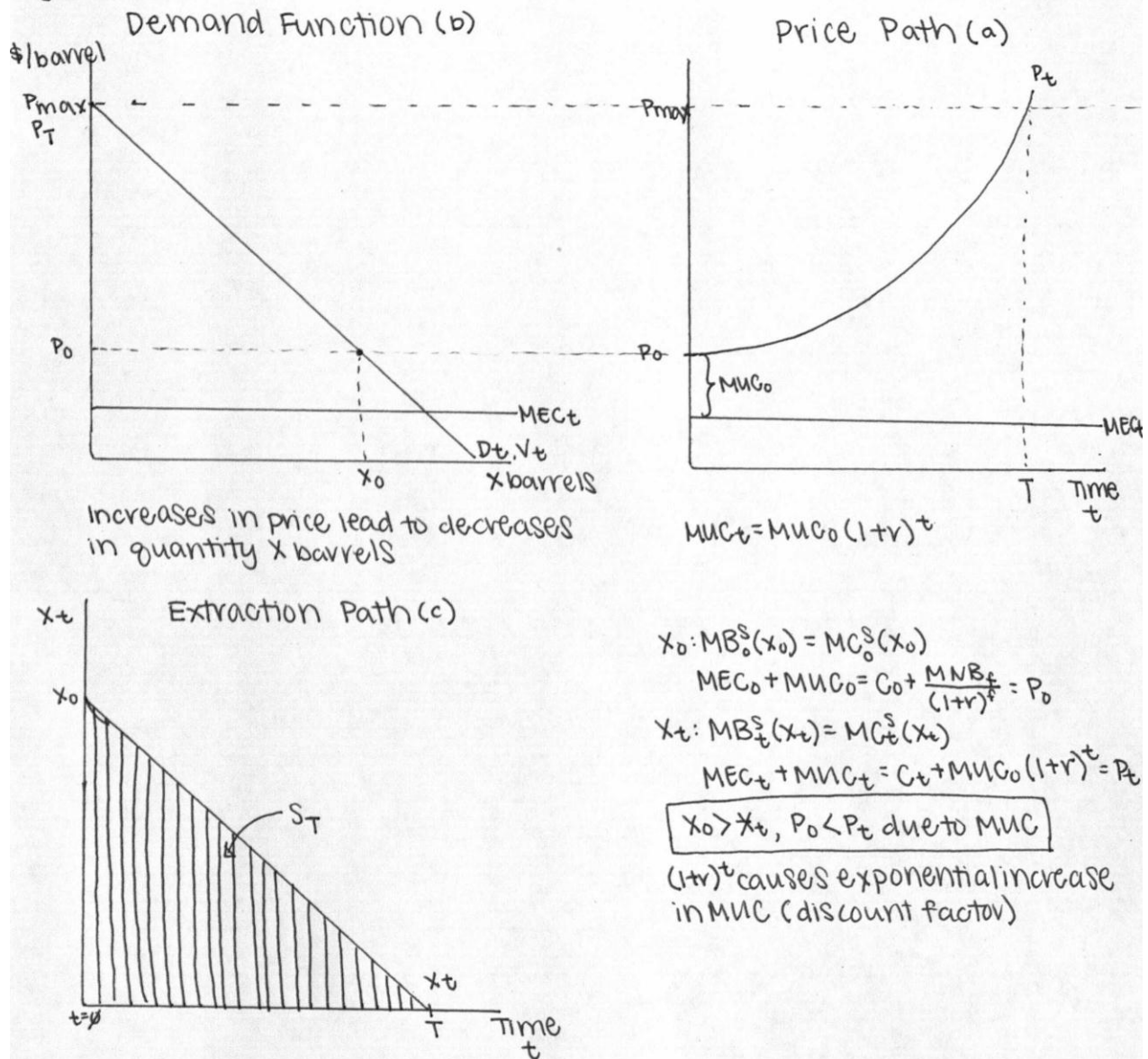
Figure 1: The Relation Between In-place Oil, Technically Recoverable Oil, and Economically Recoverable Oil



This graph illustrates the oil volume and their probability from information presented in Table 2. These curves represent the relationship between in-place oil, technically recoverable oil, and economically recoverable oil, and their respective probabilities. V_1 reflects the economically recoverable oil volume present with a 95% chance, and V_2 reflects the economically recoverable oil volume present with a 5% chance (“Arctic National Wildlife Refuge, 1002 Area, Petroleum Assessment, 1998, Including Economic Analysis,” 2001).

Figure 2: N-period Model for Non-renewable Resource Extraction

Figure 2:



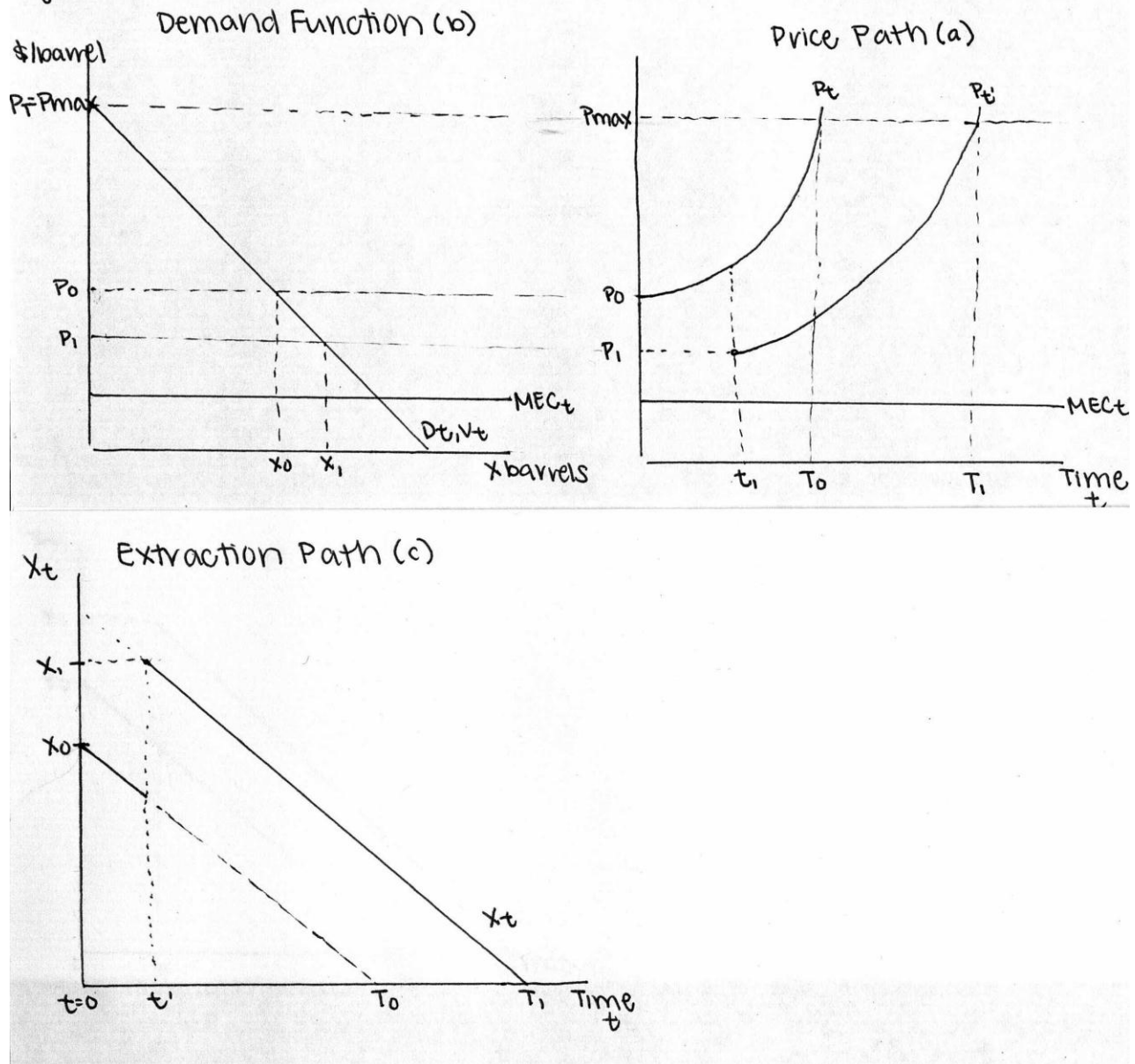
A: The Price Path increases exponentially and is composed of the MEC, which is constant, and the MUC_t , which equals $MUC_0(1+r)^t$. Economic exhaustion occurs when the price path reaches its maximum price, which is when extraction of X equals zero.

B: The Demand Function is constant and downward sloping. Starting at the initial price (P_0), the initial quantity extraction is determined as X_0 . As the price increases, shown in A, the demand function reveals a decrease in the quantity extracted until P_{max} when extraction equals zero.

C: The Extraction Path demonstrates the downward sloping function, revealed by the demand function. At terminal time, the extraction equals zero, thus the extraction path intersects the x-axis at terminal time (T). The area under the extraction path between $t=0 \rightarrow T$ represents the entire stock of the oil.

Figure 3: Effect of Entry of New Deposit into Market on the N-Period Model for Non-renewable Resource Extraction

Figure 3:



A: The Price Path is the same as in Figure 2a, but at the time of the new deposit (t') of oil, the Price Path shifts downward because with the increase in supply of the resource, the oil price decreases. After this initial entry, the price path increases exponentially by the discount factor.

B: The Demand Function is the same as in Figure 2b, but at the time of entry (t'), the extraction quantity increases ($X_0 < X'$). Over time, the price of oil will increase, causing the quantity extracted will decrease.

C: The Extraction path is the same as in Figure 2c, but at the time of entry (t'), since the extraction quantity increases and then continues to decrease as the price increases over time.